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Editor

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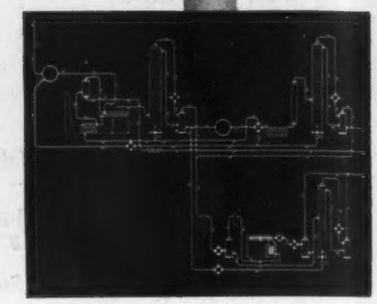

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Whether it be new equipment or modifications or additions to old, it is in the PROCESS TECHNIQUE where the dollar earning opportunity begins. No amount of expert designing or manufacturing skill can afterwards rectify a faulty process technique.

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REFINER
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The Look Box

New Crudes

ANALYSES of four new crudes are available from the Bureau of Mines. During the past month the bureau analyzed crude oil from the new Lerado field, Reno County, Kansas; Plymouth field, San Patricio County, Texas, and the Placedo field, Victoria County, Texas.

The Kansas crude is classified as a wax-bearing paraffin-intermediate base oil, 44.1° A.P.I. gravity, brownish black color, with 0.25 percent sulfur. Products recovered include light gasoline 17.7 percent, 81.° A.P.I. gravity; total gasoline and naptha 40.9 percent at 67.0° A.P.I. gravity, 16.1 percent of 44.1° A.P.I. gravity kerosene, 8.2 percent of 35.2° A.P.I. gas oil, 6.8 percent non-viscous lubricating distillate, 5.1 percent medium lubricating distillate, and 18.8 percent of 14.8° A.P.I. gravity residuum. Carbon residue of crude 2.5 percent, of residuum 13.4 percent.

The San Patricio County crude is classified as wax-free naphthene-base oil, 32.3° A.P.I. gravity, brownish green color, with 0.14 percent sulfur. Products recovered include light gasoline 7.5 percent with 69.8° A.P.I. gravity; total gasoline and naphtha 29.5 percent with 55.9° A.P.I. gravity; no kerosene distillate; 36.9 percent of 32.8° A.P.I. gravity gas oil; 9.2 percent non-viscous lubricating distillate, 3.0 percent medium lubricating oil distillate and 11.1 percent of viscous lubricating oil distillate with residuum of 8.6 percent. Carbon residue of the crude is 0.6 percent, of the residuum 7.3 percent.

The Victoria County crude is of two types. That from the Smith sand (4773 to 4778 feet deep) is a wax-free, napthene base oil, 25.2° A. P.I. gravity, brownish green color, with 0.14 percent sulfur. Products recovered include total gasoline and naphtha 2.4 percent with 46.0° A.P. I. gravity; no kerosene distillate; 57.0 percent of 31.3° A.P.I. gravity gas oil, 13.4 percent of non-viscous lubricating distillate, 3.7 percent of medium lubricating distillate, 10.4 percent of viscous lubricating distillate and 12.1 percent of 11.4° A.P.I. gravity residuum. Carbon residue of the crude is 0.7 percent; of the residuum, 5.9 percent.

The other sample of Victoria County, secured from the so-called "6000-foot sand," is classified as a wax-bearing intermediate-naphthene base oil, 35.4° A.P.I. gravity, brownish green color, with 0.16 percent sulfur. Products recovered include light gasoline 6.0 percent with 72.1° A.P.I. gravity; total gasoline and naphtha 31.6 percent with 55.2° A.P.I. gravity; 7.6 percent of 40.6° A.P.I. gravity kerosene distillate; 33.3 percent of 33.2° A.P.I. gravity gas oil; non-viscous lubricating distillate was 9.7 percent; medium lubricating distillate 3.9 percent, viscous lubricating distillate 5.9 percent and 6.7 percent of 10.7° A.P.I. gravity residuum. Carbon residue of the

crude is 0.4 percent; of the residuum 5.3 percent. Thus the Placedo field is producing from two levels, two crudes of strikingly different characteristics.

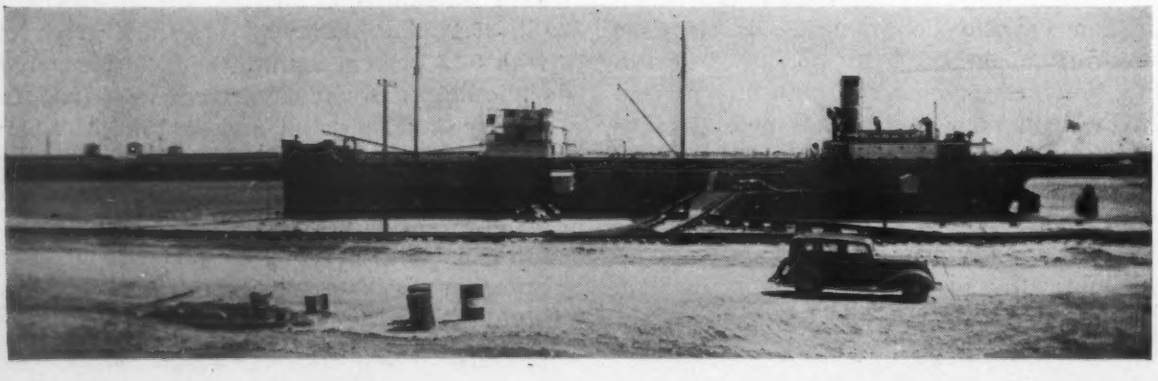
Process Development

NEXT MONTH The Process Development Number of The Refiner will bring together engineering information and flow diagrams of 27 refining and natural gasoline processes, which have reached the stage of commercial application since first publication of the original Process Handbook, February, 1932. This commercial development of 27 entirely new processes during the intervening four years is striking evidence of the rapidity of technical progress within the industry, and the correlation of this process data will prove a valuable addition to petroleum literature. Included in the schedule for the October issue is process information on 6 cracking processes; 3 polymerization processes, 12 solvent processes, 2 treating processes, 2 natural gasoline processes and 2 gas purification processes. This work is for the purpose of supplementing the original Process Handbook with the view of bringing this information data down to date.

Process Handbook

THE third edition of the Process Handbook published by The Refiner in conjunction with the 1936 Composite Catalog of Oil Refinery equipment has just been published and distributed. For the purpose of serving those who wish additional file copies of the Process Handbook a number of additional copies of this section of the Composite Catalog have been prepared and are available at the very low cost of $1.00 per copy. The Process Handbook will prove of real value to students of refinery processing, junior engineers and men just entering the industry, salesmen and distributors of refinery and natural gasoline plant equipment. The entire supply of the complete composite catalog for 1936 has been depleted, but for those wishing this modern up-to-date correlation of process information dealing with 80 processes used in this industry, the special copies of the handbook are available. Because of the limited supply of this valuable work, The Refiner can supply but one copy to any single individual. Please address orders for the Process Handbook, at $1.00 per copy, to the Book Department, Gulf Publishing Company, 3301 Buffalo Drive, Houston, Texas.

(*Continued on page 51a*)



Unusual Design Features in Michigan Cracking Unit

J. C. ALBRIGHT

CHARGING an average of 1250 barrels of reduced Central Michigan crude, Naph-Sol Refining Company, Muskegon, Michigan, is successfully converting about 56.5 percent of that type of oil to high-octane gasoline, with low fixed-gas loss. This Dubbs plant was constructed in the summer of 1935, designed especially to handle topped Michigan crude. A specific run through this plant secured the following results:

CHARGE		
Topped Crude	22/24 gravity A.P.I.	1268.05 Barrels

YIELD		
PRODUCTS	**Barrels**	**Percent**
Gasoline	719.26	56.721
Fuel oil	389.83	30.742
Gas and loss	158.96	12.537
Total	1268.05	100.000

COST	
Fuel burned	10 percent
Diesel fuel, (For hot oil charge pumps)	1.58 Barrels
Gas produced, (Per barrel charge)	536 cu. ft.

From this run, the following products were obtained:

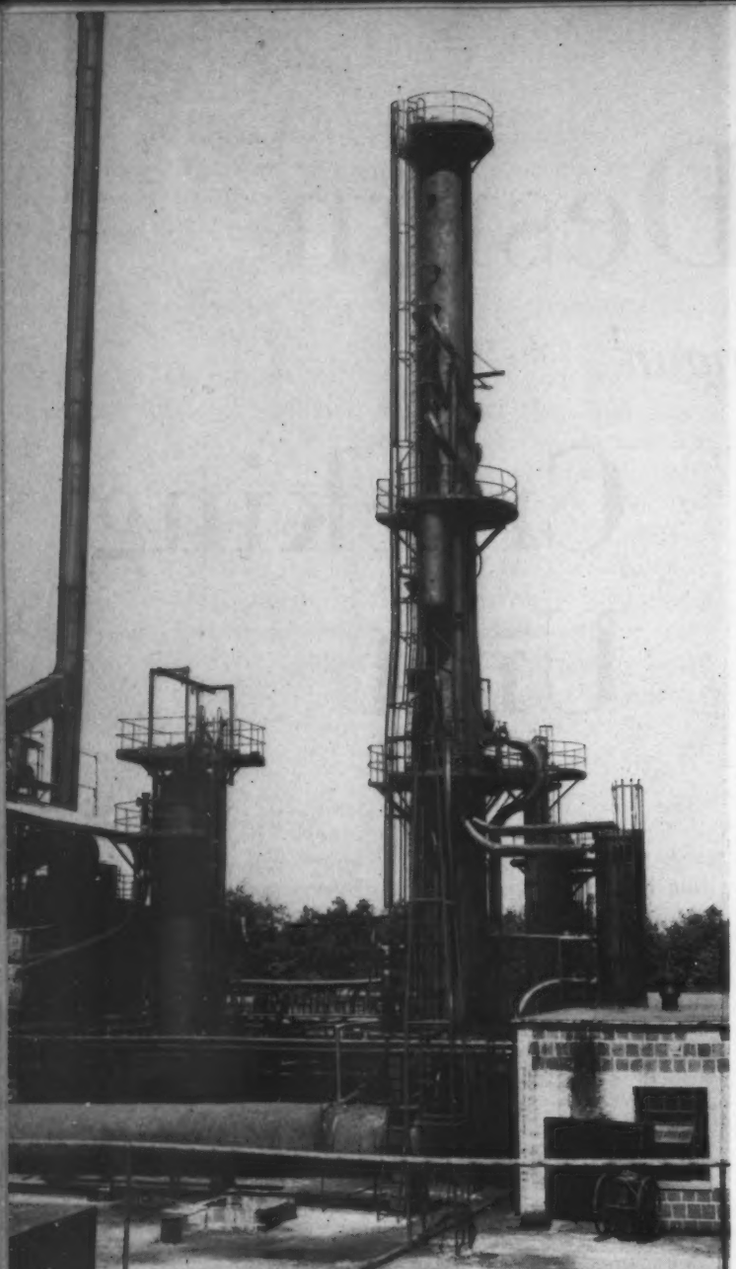
Gasoline

Gravity	61.8° A.P.I.
I. B. P.	97° F.
5 percent over	122° F.
10 percent over	140° F.
20 percent over	164° F.
30 percent over	198° F.
40 percent over	227° F.
50 percent over	250° F.
60 percent over	277° F.
70 percent over	304° F.
80 percent over	332° F.
90 percent over	362° F.
95 percent over	372° F.
End point	385° F.
Rec. percent	97
Octane	68 ASTM, CFR
Gum	5 Mgs.
Doctor	Sweet
Corrosion	Negative
Color	Natural
Fuel oil	175 Furol at 122° F.
Gravity, A. P. I.	5.5°

The cracking plant was designed by Universal Oil Products Company Engineers, and built by Naph-Sol Refining Company engineers with the various vessels fabricated by different steel companies. The general layout is similar to other cracking plants as to flow of charging stock, but the plant differs materially in some features. For example, the flash and bubble column was fabricated as one tower, with the bubble column superimposed upon the flash chamber which opens directly into the base of the former for fractionation of end-point gasoline. This combination tower is 82 feet 6 inches in height with the flashing section 6 feet in diameter and 25 feet high, built with ¾-inch walls. The top section, which is the fractionator, is 5 feet in diameter, with a height of 57 feet 6 inches, having ½-inch walls.

The furnace is another example of different construction, being designed with 2 compartments, or cells. It is fired from the top, or roof of the unit, using either gas or fuel oil with preheated air for combustion. The two sections provide means for combination feed on one side and side-cut cracking, or reforming, on the other. Both products, or charges, pass through the furnace tubes under a separate set of conditions, but meet in a common reaction chamber. Both charges mingle in the reaction chamber and pass to the flash section of the combination column where fractionation is obtained.

The topped crude, having a gravity of 22/24° A. P. I., reduced from the original Michigan high-gravity crude in the company's special products skimming plant, is picked up from cold storage by a 7½x4½x10-inch duplex steam pump and discharged through a set of fuel oil bottoms-to-charge heat exchangers where a temperature of about 300° F. is obtained, passing from this equipment to a horizontal drum for the removal of the salt in the charge. The salt-removal unit is maintained under a pressure of 165 pounds, gauge, and carries the temperature of 300° F. placed upon the oil in heat exchangers, pressure being controlled by an instrument on the outlet of the vessel. Water is used with the oil, and is introduced into the charge at the suction of the charge pump to dissolve the crys-



Naph-Sol Refining Company's cracking unit at Muskegon, Michigan, showing furnace, reaction chamber, flash chamber and fractionator

tals and assist in breaking down the emulsion while the oil is carried through the salt-removal drum.

The de-salted charge passes directly from the pressure-maintaining valve on the outlet of the salt drum to the side of the flash and fractionating column, entering above the nineteenth tray, counting from the top, where partial fractionation is accomplished. Passing downward over the stripping trays, the crude charge is again picked up from a draw-off section in the flash section of the combination column, by a duplex, outside piston-packed hot-oil pump, driven by a three-cylinder, vertical, four-cycle Diesel engine, which delivers it to the convection tubes in the heavy-oil processing section, or cell, of the furnace. Traveling immediately through the radiant bank of tubes, the oil is heated to 930° F. for passage through the transfer line to the reaction chamber.

A side cut from the thirteenth bubble deck is removed from the fractionating section of the combination column and led directly to an accumulator drum, from which it is picked up by the "light-oil hot-oil pump," a reciprocating unit 3½x12 inches, outside piston packed, driven by a single-cylinder, four-cycle Diesel engine, and passed directly to the furnace entering cell No. 2. This cell contains 32 tubes which receive the oil at 500° F. and heats it to 1030° F. at the outlet, or transfer line leading to the reaction chamber.

Heating conditions in the furnace are as follows:

Cell No 1—Heavy Oil Section

Right Near	1425° F.
Right Center	1420° F.
Right Far	1490° F.
Left Near	1500° F.
Left Center	1470° F.
Left Far	1460° F.

Cell No. 2—Light Oil Section

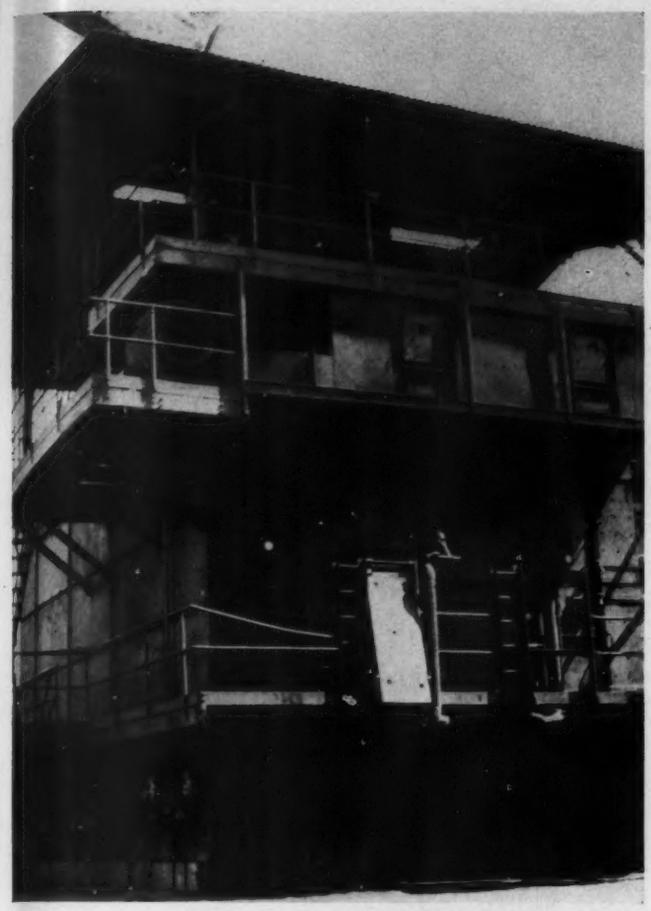
Right Near	1200° F.
Right Center	1220° F.
Right Far	1300° F.
Left Near	1310° F.
Left Center	1300° F.
Left Far	1225° F.
Flue to Stack	665° F.

Temperatures can easily be controlled at different points in the furnace because of the position and number of burners in the roof of both cells. The burner capacity is 32 units, divided into 2 sections, 16 burners for each cell, again divided by placing 8 burners on each side of the section. Controlling the fuel input to the individual burner causes a different heat input to the tubes at controlled points of the flow, and again, by controlling the direction of the burning fuel, the flames may be directed against the banks of tubes, or directed against the walls of the furnace to prevent impingment.

The transfer lines from both cells are attached to the top of the reaction chamber, connected to separate nozzles so that intimate mixing may be obtained between the two charges. The flow is from top to bottom under a pressure of 275 pounds, with the outlet at the extreme base of the chamber where the flow is controlled by a 4-inch back pressure regulating valve. The line from the base of the reaction chamber to the flashing section of the combination column carries the oil under a pressure of 63 pounds and 850° F., entering the base of the flashing section through a tangential nozzle.

Vapors evolved from the cracking charge pass upward through the flashing section and the fractionating tower, emerging as end-point gasoline at the top, which is led through a 6-inch line to condensers and receivers. Tower-top temperature control is obtained by pumping back over the top of the column a portion of the condensed gasoline taken from the distillate receiver, so that a temperature of 325° F. may be maintained.

As the distillate is condensed and accumulated in the receiver, it is pumped continuously to the final stabilizer where the vapor pressure may be reduced to that desired. The raw distillate enters the column (2 feet 6 inches by 29 feet) above the thirteenth tray (counting from the top) and is fractionated as it travels downward over the remainder of the plates. Reboiling is obtained in a horizontal vessel attached in a conventional manner to the base of the column, and is maintained at a temperature of



Furnace, above being a general view and below showing position of burners on top

about 340° F. The interior of the reboiler has a baffle at one end over which the gasoline must travel, but it is prevented from returning and must leave after coming to this point. The level in the reboiler is controlled by an instrument attached to the end fitted with the baffle, actuating a valve on the outlet of the charge-to-finished-gasoline heat exchanger.

A portion of the feed to the cracking furnace from the charge-receiving section in the top of the flashing section of the combination column is pumped through the tubes of the reboiler to maintain the desired temperature and to eliminate the use of steam for this purpose. After performing the function of a heating medium in the stabilizer reboiler, the hot oil is returned from the stabilizing equipment to the cracking equipment where it is passed through a cooling section. Passing from this equipment, the oil flows to the absorber column where it enters in the conventional manner, flowing downward over the bubble trays in the absorber counter-current to the gases entering at the base.

Gases making up the material transferred to the absorption column are taken from the distillate-receiver drum and the distillate fractionator reflux accumulator. Uncondensed gases enter the side of the absorber above the liquid section and below the bubble plates, to finally emerge from the top of the column where they are led to a recording volume meter to be passed to an industrial distribution system. The rich oil is trapped from the liquid section of the absorber and used as a portion of the quench stock, entering the line from the reaction chamber to the flash section of the combination column, pumping being necessary due to the difference between the pressure maintained upon the absorber and that of the combination column.

Application of Principles of

Stoichiometry

to Operation of Natural Gasoline Plants

DR. R. L. HUTINGTON,

Associate Professor, School of Petroleum Engineering, University of Oklahoma

EVERY gasoline plant operator should have a fairly accurate knowledge of the quantity and composition of each stream of gaseous and liquid hydrocarbons entering and leaving the plant. Only in this way can he keep in real touch with the process and know the efficiency under which it is operating. The "books" of a gasoline plant should be kept balanced i.e. the total liabilities or input (field or raw gas furnished to the plant) must always be equal to the assets or output (the products into which the gas is made). This principle of accounting is known to the chemist as stoichiometry and to the engineer as the material balance. In brief it is the application of the first law of thermodynamics or the law of the conservation of matter and energy, which states that matter and energy can neither be destroyed nor created. Most industrial plants operate by some continuous system in which the various streams are under a steady state of flow. All compression and oil absorption plants are of the continuous type, and are therefore relatively simple to study so long as they are operating under fairly steady conditions.

DATA NECESSARY FOR A MATERIAL BALANCE

Since gases and natural gasolines have relatively few pure compounds, the various flow streams may be analyzed by low temperature true boiling point columns.[2] While a few plants are equipped with gas meters on all of the important gas and vapor mains, the majority of manufacturers do not go to such a great expense in obtaining the desired quantitative data. For such plants, the material balance can be applied in estimating the quantity of gas or liquid in each stream, provided the entering raw gas is metered.

IMPORTANCE OF PROPER SAMPLING

Accurate true boiling point analyses are of little value unless the samples represent the average composition of the streams. When a liquid stream is stored over a 24-hour period, a representative sample can be obtained easily from the stock tanks into which the product is made. If the tank is under pressure the gasoline sample should be taken under the tank pressure with very little allowance for vapor space in the bomb, otherwise the vaporization of the gasoline to fill the space above the liquid would change the composition of the gasoline itself.

The sampling of gas and vapor streams calls for a higher degree of technique. Since plant balances usually are made over a 24-hour period, the gasoline content of the raw gas stream may increase in the day time due to the pumping of wells, or to the increase in vaporization of crude oil in separators and storage tanks from which the plant secures its sup-

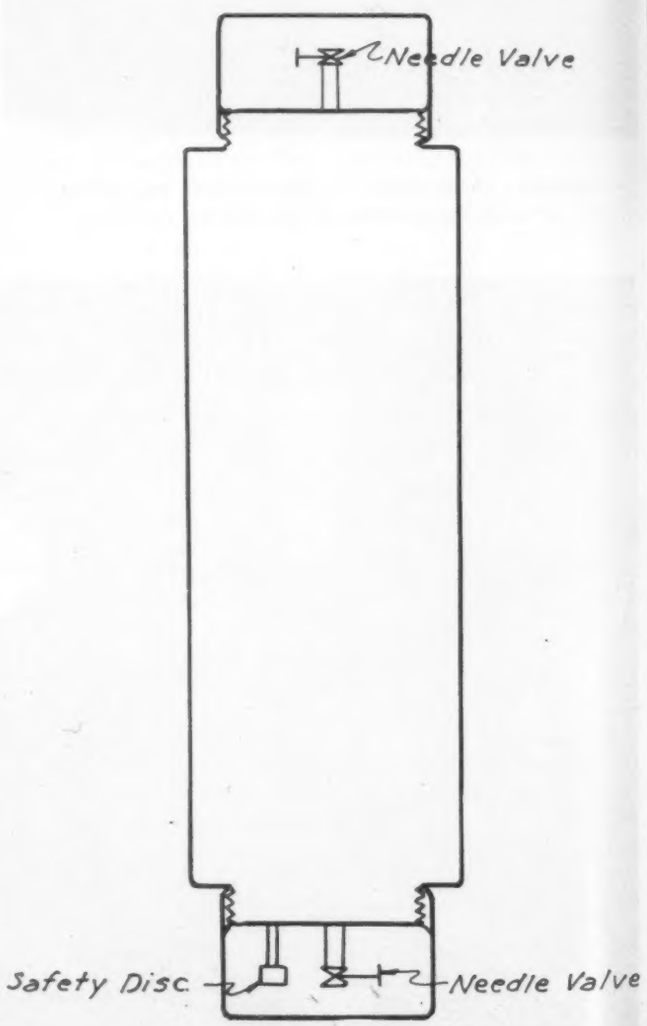
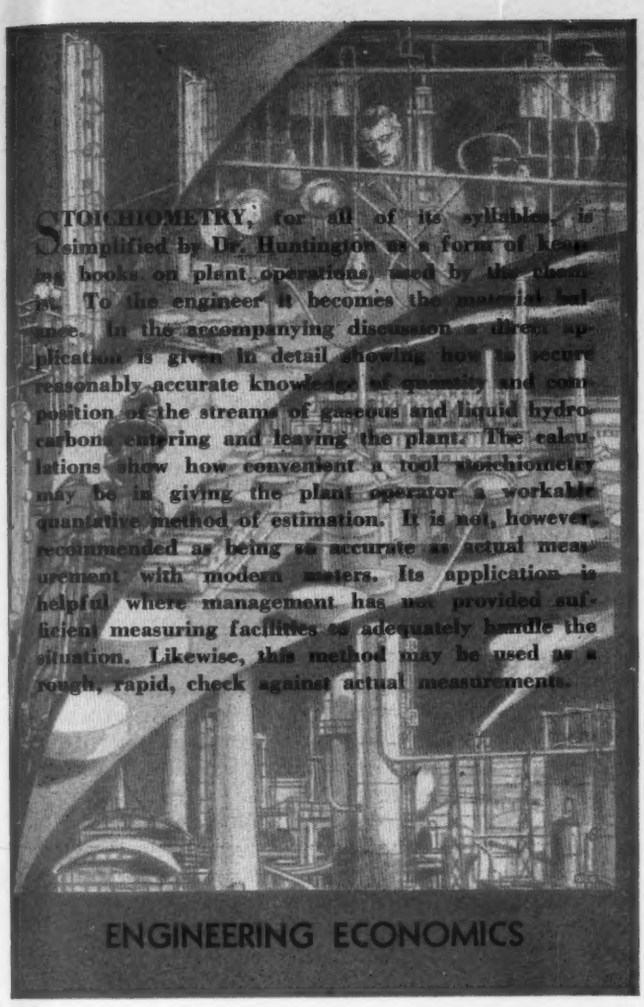


FIGURE 1

Gas Sample Container equipped with caps to protect valves from being damaged in shipment


STOICHIOMETRY, for all of its syllables, is simplified by Dr. Huntington as a form of keeping books on plant operations, used by the chemist. To the engineer it becomes the material balance. In the accompanying discussion a direct application is given in detail showing how to secure reasonably accurate knowledge of quantity and composition of the streams of gaseous and liquid hydrocarbons entering and leaving the plant. The calculations show how convenient a tool stoichiometry may be in giving the plant operator a workable quantative method of estimation. It is not, however, recommended as being as accurate as actual measurement with modern meters. Its application is helpful where management has not provided sufficient measuring facilities to adequately handle the situation. Likewise, this method may be used as a rough, rapid, check against actual measurements.
ENGINEERING ECONOMICS

ply. One of the most widely adopted methods of sampling is to fill a 5-gallon glass bottle with water saturated with sodium sulphate, in order to reduce the solubility of the gas in the water. At intervals of 4 hours about one sixth of the water may be displaced from the container by the gas sample. If the stream contains a high content of gasoline, it may not be feasible to collect the sample under a pressure, since condensation might take place in the container. In fact, in fields such as Glen Pool, Burbank or Burkburnett, the sample would have to be obtained under a pressure well below atmospheric. The use of iron containers is not recommended if chemical tests are to be made on the sulphur content of the gas, since the iron bomb might reduce the sulphur content of the sample before the test could be made in the laboratory.

If the sample container is not filled with water, the taking of a representative 24-hour sample is practically precluded. If a snatch sample is desired, the air in the container may be displaced by purging the samples with gas for 30 minutes or longer, but even then the assurance of complete air removal is not given as in the case of water displacement.

TRANSPORTATION AND STORAGE OF SAMPLES BEFORE TESTING

If the fractional analyses are to be made in a laboratory distant from the plant, the use of non-breakable metallic containers is recommended. The container (see Figure 1) should be equipped with a stainless-steel needle valve on each end, with protecting screw caps to prevent damage to the valves. As a matter of safety, the container should have a rupture disc fitting to relieve excessive pressure in case of fire. The container should be checked for leakage and for pressure at some definite temperature before shipment. At the time the analysis is made on the sample, a recheck on the pressure of the vessel is made at the same temperature. Leakage of a gas or vapor sample from a container above atmospheric pressure does not change the composition of the sample; however, leakage of air into a gas container under a partial vacuum would have to be taken into consideration by analyzing the sample for air content. Vapor leakage from a bomb containing gasoline or rich oil would change the composition of the sample to a large extent. It is always well to tip a leaky gasoline bomb so as to allow liquid instead of vapor to come through the small hole; however if a large fraction of the liquid contents leaks out, the vapor space created in the bomb would cause a drop in pressure and a change in the composition of the remaining liquid.

ILLUSTRATION OF A PLANT BALANCE

The principles involved can be illustrated best by carrying out a set of calculations on the quantities of gas, vapor and liquid being processed through a typical natural gasoline plant. A diagrammatic sketch is shown in Figure 2, of the parts of the plant which are involved in the calculation of the following problem.

A natural gasoline plant is processing 10,000,000 cubic feet of gas per 24 hours (measured at 60°F. and 14.7 pounds per square inch absolute) which is pumped under a vacuum of 10 inches from the casing heads of some oil producing wells. Due to air infiltration in leaky pipe connections of the gas gathering system, the raw gas contains 2 percent air by volume. The raw gas is compressed to 45 pounds per square inch absolute, cooled, and passed through a bubble-plate absorber, counter-current to a stream of cold denuded absorption oil. The gas leaves the absorber as residue or fuel gas. The gasoline-rich absorption oil leaving the bottom of the absorber is pumped through heat exchanger 1, and a steam preheater into a combined stripping still and rectifier. Stripped absorption oil, practically free from all gasoline fractions, is pumped from the bottom of the still through heat exchanger 1, then through a cooler, and back to the top of the absorption column. The raw gasoline vapor from the top of the still is partially condensed and collected in a small run tank. The uncondensed vapors contain sufficient pentanes and heavier hydrocarbons to justify their recovery. The vapors are therefore processed through a small "reabsorber" to relieve the main absorber of an unnecessarily heavy recycle load. The reabsorber is fed at the top, with lean absorption oil, and the rich oil from the bottom is added to the rich oil from the main absorber. The reabsorber absorbs practically all of the pentanes +, some of the butanes, but none of the propane in the uncondensed still vapors. The unabsorbed gas from the reabsorber is piped into the fuel gas system.

A part of the condensed raw gasoline from the still is used for reflux for the still, and the balance is pumped through heat exchanger II, then through a steam preheater, to a stabilizer, operating at 250 pounds per square inch absolute. All of the propane,

a part of the butane, and only a trace of the pentanes are taken overhead as a residual or fuel gas.

Finished, essentially propane free gasoline is pumped from the bottom of the stabilizer through heat exchanger II, and then through a cooler to storage.

The following data are available. All analyses are on a molal basis.

	Raw Gas Analysis, Percent	Absorber Residue Gas, Percent
Air	2.0	2.3
Methane CH_4	75.0	80.0
Ethane C_2H_6	10.0	11.6
Propane C_3H_8	6.0	4.4
Butane C_4H_{10}	4.0	1.7
Pentane C_5H_{12}+	3.0	trace

	Uncondensed Vapors from Still to Reabsorber, Percent	Residue Gas from Reabsorber, Percent
C_3H_8	68	90
C_4H_{10}	20	10
C_5H_{12}+	12	trace

	Stabilizer Residual Gas, Percent	Finished Propane Free Gasoline, Percent
C_3H_8	77	trace
C_4H_{10}	23	40
C_5H_{12}+	trace	60

Assume: That liquid volumes are additive
When liquefied 37 cu. ft. propane vapor at 14.7 lb/sq. in., 60° F.= 1 gal. gasoline.
When liquefied 31 cu. ft. butane vapor at 14.7 lb/sq. in., 60° F.= 1 gal. gasoline.
When liquefied 26 cu. ft. pentanes+ vapor at 14.7 lb/sq. in., 60° F.= 1 gal. gasoline.

Calculations to be made:

Since fractional analyses on gas and gasoline samples are subject to serious errors if not run with a high degree of skill it should be determined whether or not the analyses of raw gas and absorber residue gas are consistent.

The following calculations are based on the above data.

1. The cubic feet per day of residual gases and vapors from the absorber, from the reabsorber, and from the stabilizer.
2. The gallons of the raw-make gasoline fed to the stabilizer.
3. The gallons per day of stabilized gasoline produced.
4. The cubic feet per day of uncondensed raw-make tank vapors going to the reabsorber.

SOLUTION OF THE PROBLEM

Lewis and Radasch[1] have shown how quantitative calculations can be made on various plant streams by the selection of one or more inert components as a basis. For example, in furnace calculations the nitrogen of the air goes through the combustion space with substantially no chemical combination. It easily can be seen that none of the air, methane, or ethane appear in any stream except the absorber residue. In many cases, methane and ethane are absorbed to a certain extent by the oil, but even in those cases these two first members in the paraffin series can be treated as inert components.

Residue Gas from Absorber.—Taking 1000 standard cubic feet of raw gas as a basis for the calculations it is observed that the inert gases in the incoming stream amount to 87 percent or 870 cubic feet, and the same three components represent 93.9 percent of the absorber residue. Since 870 cubic feet equals 93.9 percent of the residue gas, the total amount of residue gas would be

$$870 \times \frac{100}{93.9} = 927 \text{ cu. ft.}$$

Consistency of Analyses.—Since air, methane, and ethane pass through the absorber without being absorbed, the ratio of the percentage of each of these constituents in the raw gas, to its respective percentage in the residue, should be a constant, as shown by the following calculations:

	Percent by Volume		Ratio
	Raw Gas	Residue Gas	Raw/ Residue
Air	2.0	2.3	.870
Methane CH_4	75.0	80.0	.938
Ethane C_2H_6	10.0	11.6	.862
Total	87.0	93.9	.927

Although there is an extreme variation of about 9 percent between the several ratios, the analyses are as consistent as one could expect due to experimental inaccuracies which are very difficult to overcome. A small error in the analysis of the air content would have a marked effect on its ratio of raw to residue. For this reason it is better to select the ratio of the raw to residue for the total of the three components since poor fractionation of the methane would cause it to show up as ethane. If any one of the three components were to be taken as a basis, methane should be chosen as it is present in the highest percentage.

Gallons of Stabilized Gasoline.—Since practically all of the pentanes and heavier constituents leave the plant in the stabilized gasoline it is evident that the 30 cubic feet of pentane in every thousand cubic feet of rich gas makes up 60 mol percent of the gasoline. As mol percent is equal to volume percent in the vapor, there must have been 20 cubic feet of butane condensed to make up the remaining 40 mol percent of the gasoline. Fifty cubic feet of butane and pentane therefore represents the amount required to produce the gasoline leaving the stabilizer.

	Cu. Ft. Vapor	Cu. Ft. Vapor Gal. Gasoline	Gals of Gasoline per 1000 Cu. Ft. Raw Gas
Butane	20	31	.645
Pentanes	30	26	1.150
			1.795

$$\text{Gasoline per day} = \frac{10{,}000{,}000}{1000} \times 1.795 = 17{,}950 \text{ gallons}$$

Residue Vapors from the Reabsorber and Stabilizer. The total number of cubic feet of vapor leaving the reabsorber and stabilizer is equal to the raw gas (1000 cu. ft.) minus (1) Absorber Residue (927 cu. ft)
(2) Vapor to make gasoline (50 cu. ft.)

977 cu. ft.

or 1000 — 977 = 23 cu. ft.

The amount of propane in the absorber residue gas is 927 × .044 = 41.0 cu. ft.

Since 60 cu. ft. of propane enter with the raw gas, 60 — 41 = 19 cu. ft. of propane leave the reabsorber and stabilizer.

If we let X equal the number of cu. ft. of vapor leaving the

reabsorber, (23 — x) will equal the cubic feet of stabilizer residue vapor.

A propane balance on these two streams is as follows:

Reabsorber		Stabilizer	
Propane .9	×	.77 (23 — x)	= 19

x = 10 cu. ft. of reabsorber residue per 100 cu. ft. of raw gas

or $\frac{10{,}000{,}000}{1000} \times 10 = 100{,}000$ cu. ft. per day of reabsorber residue.

The stabilizer residue equals

23 — 10 = 13 cu. ft./1000 cu. ft. of raw gas

or $\frac{10{,}000{,}000}{1000} \times 13 = 130{,}000$ cu. ft. per day of stabilizer residue vapor.

Gallons of Raw Make Gasoline to Stabilizer.—The raw gasoline equals the finished gasoline (1.795 gals.) plus the overhead condensate from the stabilizer. The stabilizer overhead equals

	Cubic Feet	Cubic Feet/ Gallons	Gallons
C_3	10	37	.27
C_4	3	31	.097
			.367

Therefore the raw gasoline per 1000 cu. ft. of raw gas is

1.795 — .367 = 2.162 gallons or

$\frac{10{,}000{,}000}{1000} \times 2.162 = 21{,}620$ gallons per day.

Cubic Feet of Uncondensed Raw-Make Tank Vapors. There are 73 cubic feet of vapors in the rich oil. All of these vapors enter the make tank, either as vapor or liquid. Since the liquid or raw make gasoline, if vaporized, would equal the total of the two streams leaving the stabilizer or 63 cubic feet, it is seen that 73 — 63 = 10 cubic feet of vapor enter the reabsorber due to the incoming raw gas. In addition to the 10 cubic feet of vapor coming from the rich oil out of the absorber, there is a recycle vapor load due to the butane and pentanes dissolved in the rich oil from the reabsorber. If we let x equal the number of cubic feet of recycle vapor, the following relationship will give a solution:

Propane balance on reabsorber

Input = Output

Propane .68 (10 + x) = .9 × 10

x = 3.24 cu. ft. of vapor recycled through rich oil/1000 cu. ft. raw gas

or $\frac{10{,}000{,}000}{1000} = 32{,}400$ cu. ft. of vapor per day absorbed by oil passing through reabsorber.

The amount of uncondensed make tank vapors is 10 + 3.24 cu. ft./1000 cu. ft. raw gas or $\frac{10{,}000{,}000}{1000} \times 13.24 = 132{,}400$ cu. ft. per day.

The calculations which have been given, show how convenient a tool stoichiometry may be in giving the plant operator a quantitative method of estimating various gas, vapor and liquid streams. Meters, of course, give more accurate results, since the material balance is dependent upon fractional analyses. Then too, it is not always possible to find a set of analyses where substantially all of one or more constituents go through a tower in one direction only, such as the inert gases in the case of the absorber. This exception probably would show up with a high pressure absorber where appreciable percentages of methane might be absorbed. In the absence however of convenient methods for measuring various gas and liquid streams, the plant material balance generally offers a satisfactory solution, although certain simplifying assumptions may have to be made in order to carry out the calculations.

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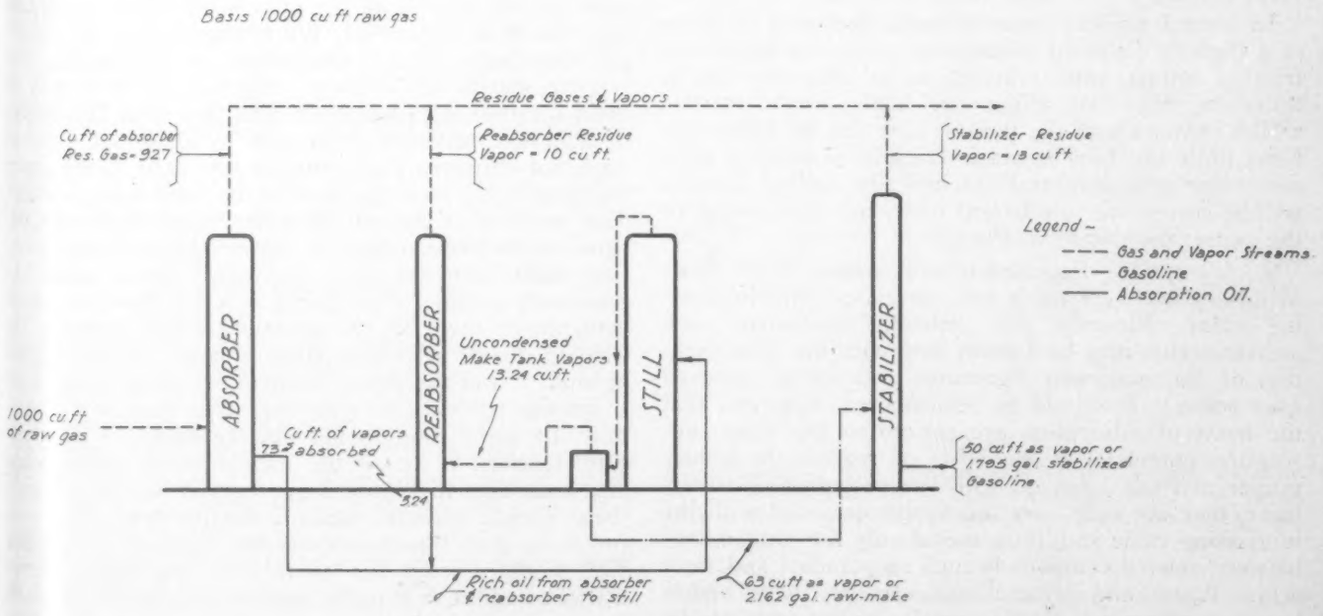
Basis 1000 cu ft raw gas
Residue Gases & Vapors
Cu ft of absorber Res. Gas = 927
Reabsorber Residue Vapor = 10 cu ft
Stabilizer Residue Vapor = 13 cu ft
Legend –
Gas and Vapor Streams
Gasoline
Absorption Oil
ABSORBER
REABSORBER
STILL
STABILIZER
Uncondensed Make Tank Vapors 13.24 cu ft
1000 cu ft of raw gas
Cu ft. of vapors absorbed
73
924
50 cu ft as vapor or 1.795 gal. stabilized Gasoline
Rich oil from absorber & reabsorber to still
63 cu ft as vapor or 2.162 gal. raw-make

FIGURE 2

Diagrammatic Flow Sheet of Natural Gasoline Plant showing calculated quantities of various gaseous and liquid streams

Oiliness

Its Meaning and Value In Motor Oils Practice and Theory

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PART III

Adsorption Phenomena and Orientation on Surfaces General

THE successes, notable of Langmuir, Harkins and Hardy's pioneer work in this field are too well known to need detailed explanation; the same holds of Adam's continuation of Langmuir's researches on molecular orientation on water surfaces.[17] We have to bear in mind that we are dealing with solid surfaces and condensed states of the matter adsorbed. At first sight it might not look very hopeful to try to understand or even predict adsorption and orientation phenomena in ignorance of the exact constitution of many of the substances concerned. Fortunately, there is enough experimental material available, and for a general survey and a few very useful conclusions such detailed knowledge is not utterly indispensable.

In Part I evidence was brought forward in favor of a slightly different conception as to how boundary friction enters into lubrication in practice which, however, does not affect our basic considerations which center about the points: how are the boundary films built up, how is static friction connected with molecular structure and—technically—which factors will be conducive to efficient boundary lubrication in the sense, developed in Part I?

9. *Adsorption*—Repeated measurements on the heats of adsorption were made and correlated with lubricating value. Properly and critically evaluated, such measurements may be a great help with due consideration of the molecular structures and forces involved (see below). It should be remembered, however, that the heats of adsorption are related to the actual adsorption potentials as the heats of reaction to affinity proper and not identical with the potentials. Furthermore, they are only very indirectly connected with the lubricating value and, thus, useful only for comparisons between related compounds such as paraffins and fatty acids. Water and glycerol will certainly have higher heats of adsorption than mineral oils and certainly be inferior lubricants.

It is well known (and demonstrated by friction measurements by Hardy and Doubleday[18]) that in a mixture of non-polar and polar molecules, fatty acids and paraffins, the boundary layer is exclusively built up by the polar molecules as long as there are enough present. Let us consider the forces involved. A rough estimation already shows that the contribution of the induction effect (E_i) will be small, so that we may neglect it for an approximate consideration. There remain the dipole (or "alignment" or orientation) effect (E_o) and the dispersion effect of (E_D). Of these, E_o varies as μ^2/r^3 and E_D as $\alpha^2 . V_1/r^6$ while E_i varies as $\alpha . \mu^2/r^6$. Now, assuming that both the paraffin and the acid molecules (of equal length) approach the adsorbing surface with the H atom of the CH_3 and COOH groups respectively, then the E_D contribution will be about the same for both, the polarizabilities of these groups being $\alpha_{OH} = 1.03 . 10^{-24}$ and $\alpha_{H-} = 1.46 . 10^{-24}$. The dipole moments of the COOH and C-H groups are, however, $1.5 . 10^{-18}$ and $0.1 . 10^{-18}$ and, entering as the square, the ratio of the dipole forces should be $2.25/0.01 = 225/1$. We see that the E_o contribution is very small where the dipole moments are small and practically negligible with the hydrocarbons, as stated in paragraph 6. However, our above calculation of the E_o contribution neglects the fact that with the anchoring dipole force only the vertical component of the moment becomes effective. Measurements suggest that this component is of the order of $0.2 . 10^{-18}$ with the fatty acids. Thus we obtain the ratio $0.04/0.01 = 4/1$. We recognize how important the knowledge of this component is for judging the relative merits of "oiliness" additions with regard to their firmness of adsorption. The fact that the works of adhesion on water differ only by about 100 percent does not disprove that estimate which is based upon the simplifying assumptions that the dipoles are isolated. The work of adhesion on water must obviously depend on the arrangement of the molecules. These questions have been examined by Adam[19] in his book. As previously pointed out (paragraph 8) there is ample evidence in favor of the assumption that, notably the smaller dipole molecules form clusters in the liquids in bulk[7-10] and the dipole moment shows in these cases a definite tendency to decrease. This greater "saturation" by association should also be expected on energetic reasons. It means the formation of quadrupoles, etc., according to Figure 2 (paragraph 6). As a result, there should remain chiefly induction and dispersion forces in such liquids responsible for their properties. This would account for the relative magnitudes of the works of adhesion actually measured. It would account, furthermore, for the increase of this work in the paraffin series with increasing molecular weight, i.e., chain length and for certain differences in the orientation phenomena when HCl is added to the water.[20] Moreover, we should bear in mind that the moments of

molecules with polar heads become more and more screened by dipole association and increase in chain length.

In considering the density of packing of adsorbed molecules (important for film strength), their structure, intramolecular mobility, their ways of association and the forces involved, provide useful hints. Comparing the crystalline and adsorbed states with polar molecules (Figures 3 and 4), for instance, shows that the dipole forces must be differently saturated in both cases, because in the former case there are always two rows with opposed moments available for mutual saturation. While a molecule with a moment strictly perpendicular to the surface would repulse its neighbors, any other arrangement of the moment within a flexible molecule will lead to a distortion of the molecule as required by the minimum of mutual potential energy. For such reasons, in the series: n-paraffins, alcohols and fatty acids, the adsorbed paraffin molecules should be less closely packed because their induced moments are certainly lying in the same direction, repulsing each other. In the alcohols the OH-dipoles are free to interlock and thus to favor a closer packing, while with the acids, the space occupied by the CO-group, notwithstanding the interlocking action of the CO- and OH-moments, does not permit as close a packing as in both other cases.

In mixtures of polar molecules as they occur in lubrication, as a rule, and as was actually demonstrated by the author, the higher dipole moment (provided it is accessible) will displace the lower on the surface. This behavior of polar groups and these considerations are

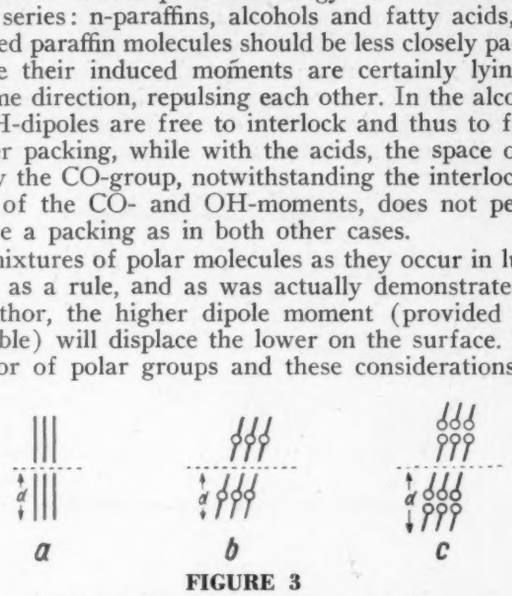

FIGURE 3

Molecular Arrangement in Crystals. dotted line=plane of cleavage; d=unit. a . . . n—Paraffins; b . . . Ketones and Esters; C . . . n—Alcohols and Acids.

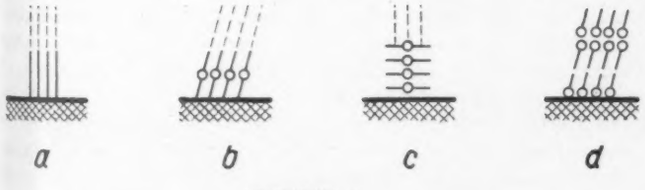

FIGURE 4

Natural Arrangment of Films on Surfaces. a . . . n—Paraffins, b, c, . . . Ketones and Esters; d . . . n—Alcohols and Acids.

important for the judgment of the efficiency of polar additions to oils as anti-corrosive agents (see Part I.). The efficiency of these, thus, depend both on the magnitude and on the accessibility of the moment. A critical examination of possible "oiliness" additions on these lines would lead too far in this paper, the purpose of which is an introduction into the fundamental phenomena.

The question of the thickness of boundary films shall be treated in brief in connection with surface orientation.

10. *Orientation of molecules on surfaces and boundary friction.* While the works of Langmuir and Hardy and, later Adam remain the standard on this subject, their results are supplemented by more recent X-ray experiments and by our knowledge on the liquid state, molecular structure for forces. Thus, definite orientation on surfaces follows from the consideration of the molecular forces effective in adsorption and from consideration of the minimum of potential energy which determines the molecular arrangement. From such considerations in paragraph 7 the orientation of the n-paraffins on solids was derived in harmony with recent evidence by Trillat and Motz[22] by means of electron diffraction patterns. The well-known orientation of hydrocarbon chains with polar head was discussed as a specimen case of adsorption. There remains only the case of compounds where the polar group is located between two chains, for which the ketones offer an example. In these cases the very large moment ($2.7 \cdot 10^{-18}$) of the CO group is screened in the two longitudinal directions, however, it is well accessible from the side. The rigidity of the molecules, especially in the condensed states, requires an arrangement flat on the surface according to Figure 4c for the minimum of potential energy. Figure 3 shows the arrangements in crystals, which was also found to be still preserved in the films.[22] It follows that, in principle, in the films of the ketones, two arrangements are possible, a "paraffin like" (Figure 4*b*) and a flat, polar one (Figure 4*c*), of which only the latter is stable because of energetic reasons. This arrangement was, moreover, confirmed by the author on friction measurements.[23]

Figure 5 represents the static friction μ data of Hardy and Doubleday on the n-paraffin series of paraffins, alcohols and acids as functions of the chemical molecular weight M. Figure 6 represents the same data plotted against multiples of the molecular weights M' as suggested by the author elsewhere.[23] A, B, C represent the lines for n-alcohols, paraffins and acids respectively, with the corresponding molecular weights $M' = M$; M and 3 M and for formic and acetic acid $M' = 4$ M. This representation preserves in contrast to Figure 5 the principle of uniform increase of μ with each added CH_2 group in the chain in all of the three series and rests, furthermore, on considerations of dipole association. It follows from this interpretation that, to all probability Hardy's primary films, i.e., the films operative in boundary lubrication, should be one molecule

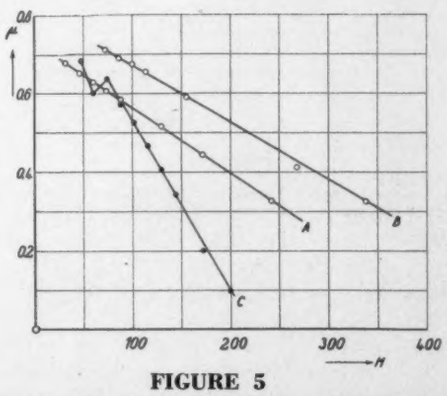

FIGURE 5

***μ coefficient of static friction, M molecular weight; on glass. A . . . n—Alcohols, B . . . n—Paraffins, c . . . n—Acids.* (from Hardy and Doubleday, Proc. Roy. Soc. (A) 100. 550. (1922).)**

thick with paraffins and alcohols and three with the acids. This difference may scarcely be attributed to a difference of polarizability. Furthermore, any polarizing effect of the polar head on the chain attached to it can scarcely be made responsible for the strong apparent chain-building effect of the long-chain acids, because,

as spectroscopic evidence shows,[25] the polarizability of the C-C bond is too small to transmit any influence of the C=O group. For such reasons we are led to the hypothesis that the cause of the different behavior is the different anchoring to the surface of the molecules. From the considerations of paragraph 9 and from structural reasons it follows that, as to the anchoring area on a solid surface, it can be said rather certainly that an alcohol should behave more like a paraffin, whereas an acid should show a greater difference. Such a difference in anchoring area must result in a different angle of tilt, a different distance of the CH_3 end groups from each other and, thus, in a different degree of homogeneity of the field of these end groups; i.e., the "adsorption" lattices will be slightly distorted compared with those of the following layers. In this connection it should be recalled that, with crystals, cleavage planes are the planes where molecules are packed most closely, i.e., where the field of force is most homogeneous: the more homogeneous it is, the smaller is the resistance against separation. Now, the coefficient of static friction corresponds to cleavage resistance and our deductions show how the same end groups may produce a different coefficient or friction. To the same resistance against separation there should correspond in our case a chain length which should be greater in the case of an acid than in both of the other cases.

In a fundamentally similar way it may be explained why the friction coefficients decrease with increasing length of the molecules within a series. For instance: applying the theory of Silberstein according to Figure 1*b* to the adsorption layer, we should expect a weakening of the lateral force fields, an influence decreasing with the distance to the effect that the CH_3 end groups come nearer together as the distance from the surface increases. Research on these lines is in progress.

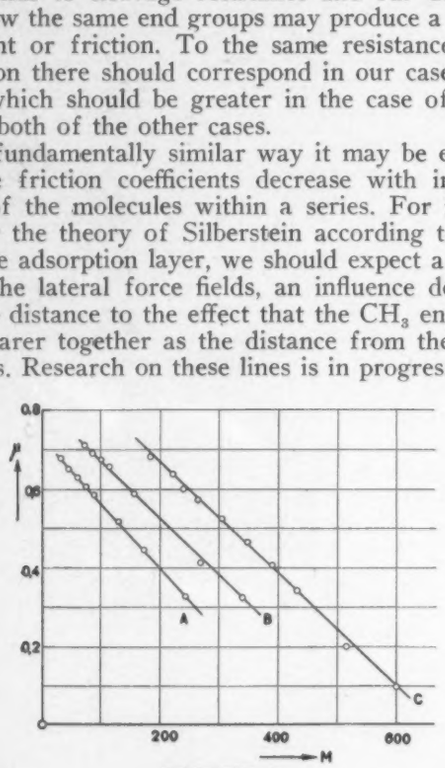

FIGURE 6

μ coefficient of static friction; M′ molecular weight=x.M
A . . . n-Alcohols, B . . . n-Paraffins, C . . . n-Acids.
M′= .M; .M; 3.M

These hypotheses are so far in harmony with Figure 6.

From the point of view of practical safety or film "toughness," strong lateral molecular cohesion is recommendable. The principles conducive to this effect shall be briefly recalled: in general with hydrocarbons the dispersion forces will determine lateral cohesion which forces are proportional to the area of "contact." The possibility of close packing will add to the effect, while any polar groups or C=C bonds, the latter by their high polarizability, will also contribute considerably to the cohesion.

With regard to the high temperatures existing in motor operation we must briefly deal with the effect of temperature on orientation. The experiments of Hardy on friction and X-ray patterns of Trillat show that orientation is still undisturbed above 100°C. in adsorption layers. The same is shown by experiments of Langmuir[26] on adsorbed oxygen on tungsten at about 1200°C. This tends to show that in this respect the adsorbed molecules tend to behave like an integral part of the adsorbing surface. Experiments by Noll[27] on liquid ether show that oriented states in liquids in bulk are still noticeable up to nearly 200°C. The superiority of polar additions at motor operating temperatures is furthermore demonstrated by the practical tests described in Part 1.

From a theoretical point of view we should bear in mind that the effect of temperature on the solid surfaces will be chiefly an increase of the vibrational amplitude of the atoms, i.e., of the "anchoring" points. Furthermore, the disturbing effect of temperature on dipole orientation cannot become as effective as in a liquid in bulk, the adsorbed layer being, as far as mobility is concerned, much more comparable to its crystalline state. Also for these reasons it is to be expected that a marked contribution of the dipole forces will still persist at higher temperatures.

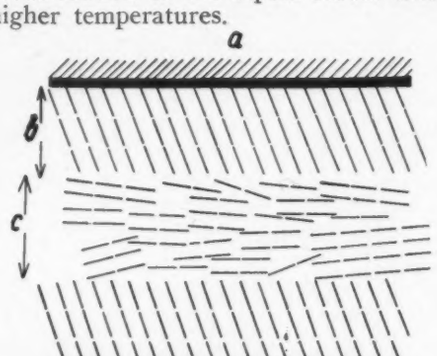

FIGURE 7

Model of Lubricating Layer, (in motion).
a metal, b boundary layer, c range of flow orientation.

The actual thickness of oriented layers of molecules in a lubricating film will vary with temperature and with the relative speed of the lubricated surfaces. Consequently, in Figure 7 which represents schematically and generally a lubricating layer in motion, this transition layer remains indeterminate. The same holds of the angle of tilt of the molecules in the primary layer *b* and of the size of the complexes in the region of flow orientation *c* which, moreover, will scarcely be uniform throughout the liquid. The grouping with a maximum of saturation of the polar groups (dipole association) of polar molecules both in the boundary layer and in the liquid is indicated in Figure 4 *c* and *d*.

A general survey of the results of our deductions and a comparison with practical experience show that the methods of modern molecular physics are applicable in lubrication and oil research with as good results as they have proved to be again and again in chemical research.

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Economies in

Hypochlorite Treating

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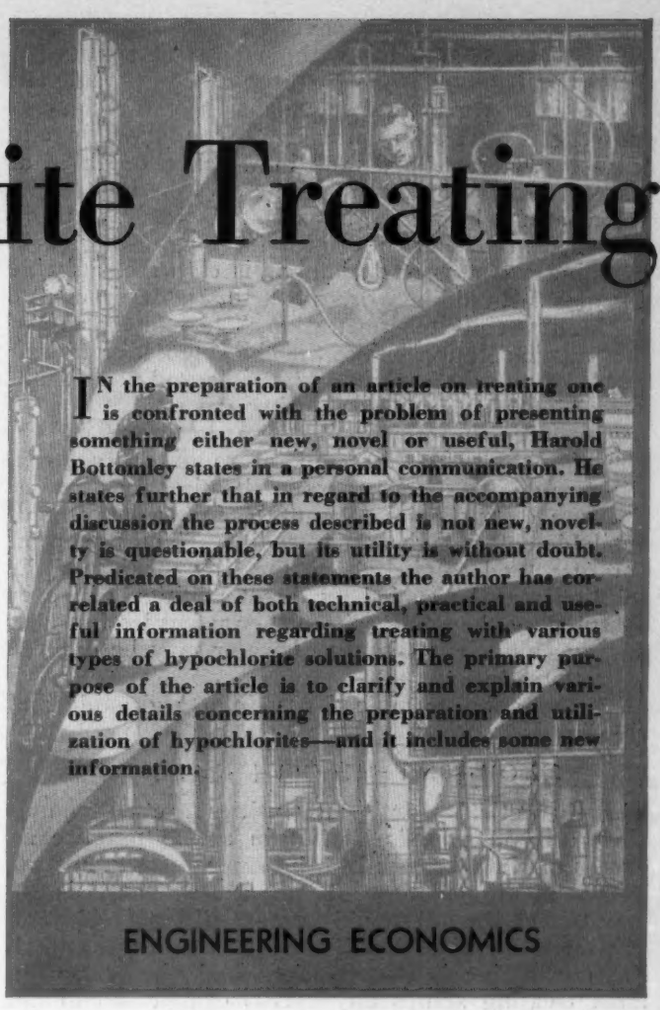


IN the preparation of an article on treating one is confronted with the problem of presenting something either new, novel or useful, Harold Bottomley states in a personal communication. He states further that in regard to the accompanying discussion the process described is not new, novelty is questionable, but its utility is without doubt. Predicated on these statements the author has correlated a deal of both technical, practical and useful information regarding treating with various types of hypochlorite solutions. The primary purpose of the article is to clarify and explain various details concerning the preparation and utilization of hypochlorites—and it includes some new information.

ENGINEERING ECONOMICS

THE actual process of treating petroleum distillates with an oxidizing hypochlorite solution is simplicity itself, provided a few simple precautions are taken regarding composition of treating solution, temperature of treatment and nature of products treated. While hypochlorite has its place in the treating schedule of almost any refiner it cannot be used indiscriminately and without due regard for its peculiar properties. It is especially adaptable to the treating of straight-run products, naturals, and recovery gasolines. Any material of a reasonable unsaturated nature will of course be attacked by the extremely active oxygen of the hypochlorite and gums will result, but, as stated above, its use must be judiciously applied.

Hypochlorite solution is amenable easily to either batch or continuous treating. If treating by batch, the agitator is charged in the usual manner, and precautions are taken to have the product H_2S free, as the interaction between hydrogen sulfide and hypochlorite liberates free sulfur that will dissolve in the oil. The reaction is

$$H_2S + NaOCl \rightarrow NaCl + H_2O + S$$

Hypochlorite is pumped into the agitator and circulation or blowing begun. It has been found that either does the work efficiently, the blowing probably being a little faster. However, the circulation method obviates any possibility of excessive evaporation and possible flashing of light distillates. The solution then is circulated with the oil until sweetening is effected or the hypochlorite is spent of its oxidizing power. If the hypochlorite spends before the oil is sweetened it must be drawn off and new added. That drawn off as spent should be retained for its caustic content for use as wash on distillate streams containing H_2S.

The amount of hypochlorite solution required to sweeten any given batch of petroleum distillate naturally will depend on the available oxidizing power of the treating solution and the degree of sourness of the product to be sweetened. It will be found that for any constant source of crude supply the oxygen requirements for sweetening will lie within remarkably close limits. A discussion of oxygen requirements will be given farther along in the article. Figure 1 shows a possible hookup for batch treatment with hypochlorite.

If a continuous treating system is desirable it may be employed in the same manner as would any other type continuous-treating system using mixers for the reagents and a series of towers acting as settlers for the caustic, hypochlorite and water wash. In some installations the water wash may be omitted entirely, depending upon whether a light or heavy product is treated and the season of the year. In Figure 2 is shown a simple continuous-hypochlorite treating system.

In the foregoing discussion hypochlorite has been used as a general term with no adjective describing the type such as calcium or sodium. Either may be used according to "local option." The economics of choice will be discussed later.

Sodium hypochlorite generally is prepared from sodium hydroxide and chlorine, by expanding the chlorine directly into an optimum strength of the caustic. Soda ash may be used as the alkali but it has its several disadvantages such as bulkiness, getting into solution, etc. A moderately active hypochlorite solution for petroleum product treating should consist of 10-12 grams per liter of available chlorine and an excess alkalinity of at least 4.0 grams per liter NaOH. The hypochlorite solution is made up in a concentrated form of 50-60 grams per liter available Cl and then diluted with water to give the desired 10-12 grams per liter. By doing it in this manner the preparation is speeded up and danger of over chlorination minimized. In actual practice the strong hypochlorite solution is prepared as follows: Into 1000 gallons, or multiple thereof, of 15° Be. sodium hydroxide are expanded 600 pounds of

chlorine either liquid or gaseous. This solution when diluted to 7200 gallons with water will contain 10 grams available chlorine per liter or 4.5 grams available oxygen per liter. The expansion of the chlorine into the NaOH solution may be conducted in any lead- or concrete-lined tank in which a depth of at least 18 inches in kept above the chlorine inlets. The chlorine may be passed in as fast as the NaOH will absorb it, the usual precautions being observed in handling a gas as hazardous as is chlorine. Suitable gas masks should be worn by the operators in charge of the hypochlorite preparation. The temperature of the caustic solution before the chlorine addition preferably should be as low as possible and should not exceed 100° F. maximum during the preparation. A conservative and safe upper temperature is 95° F. During expansion the temperature of the solution will rise due to the exothermic chemical reactions at the rate of approximately .6° F. for each gram of available chlorine absorbed per liter. Should the temperature tend to rise above the safe maximum the solution may be cooled by direct addition of ice or by submerged cooling coils. When using ice for cooling, an equivalent amount of water may be omitted from the solution.

The reaction formula for sodium hydroxide and chlorine is

$$2NaOH + 2Cl \rightarrow NaOCl + NaCl + H_2O$$

The theoretical reacting quantities are 80 pounds NaOH to 71 pounds Cl but in actual practice an excess of NaOH is used to the extent of 4 grams per liter as mentioned above. If this excess NaOH is not maintained the solution is potentially unstable and subject to deterioration. The higher the excess alkali the less active is the solution, and vice versa. In most treating setups any excess caustic would not be wasted but would be used for the purpose of H_2S removal from distillate streams after being spent of its oxidizing power. Contrary to some opinions, no agitation of the alkali is necessary when passing chlorine into sodium hydroxide as the natural convection currents set up are sufficient for this purpose. With a less soluble alkali some artificial stirring is helpful. The chlorine is absorbed readily and no evolution takes place from the solution if the temperatures and alkalinity are held according to the foregoing directions. After dilution to 10 grams/liter a small amount of agitation may be necessary to properly distribute the heavier layer of concentrated sodium hypochlorite.

Soda ash also may be used in preparing sodium hypochlorite. Thirteen hundred pounds of 58 percent soda ash are dissolved in 1000 gallons of cold water and into this are passed 350 pounds of chlorine, observing the same precautions as those mentioned under the preparation from sodium hydroxide. This concentrated hypochlorite is then diluted to 4000 gallons and agitated. It is then ready for use. The essential reaction for Na_2CO_3 and Cl is

$$Na_2CO_3 + 2Cl \rightarrow NaOCl + NaCl + CO_2$$

Hypochlorous acid is formed as an intermediate but in the presence of the sodium carbonate reacts to give the hypochlorite, salt, and carbon dioxide.

In the preparation of calcium hypochlorite the required amount, 500 pounds, of hydrated lime is mixed with 1000 gallons of cold water and into this slurry, well agitated, is passed 420 pounds of chlorine. It is important that a sufficient level be maintained above the chlorine inlets and that the agitation be complete for efficient absorption of the chlorine. After preparation, the excess lime and sludge is allowed to settle and the clear liquor either de-

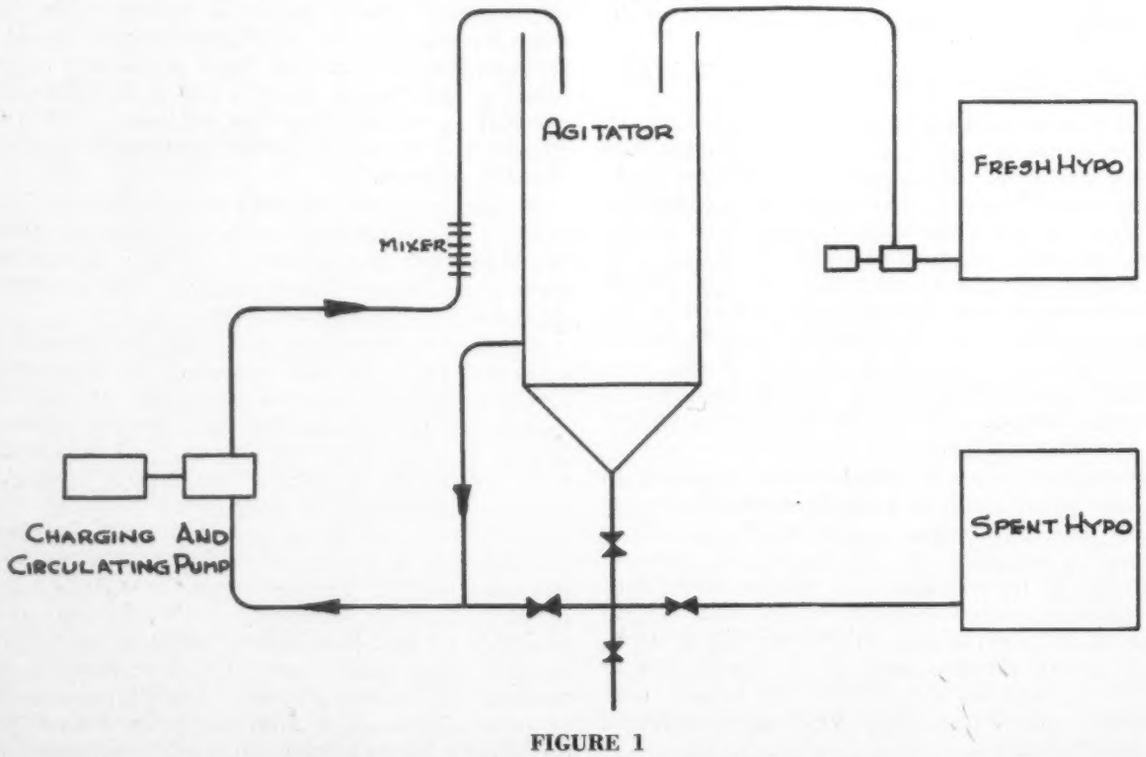


FIGURE 1

A typical hook-up for bath treatment with hypochlorite

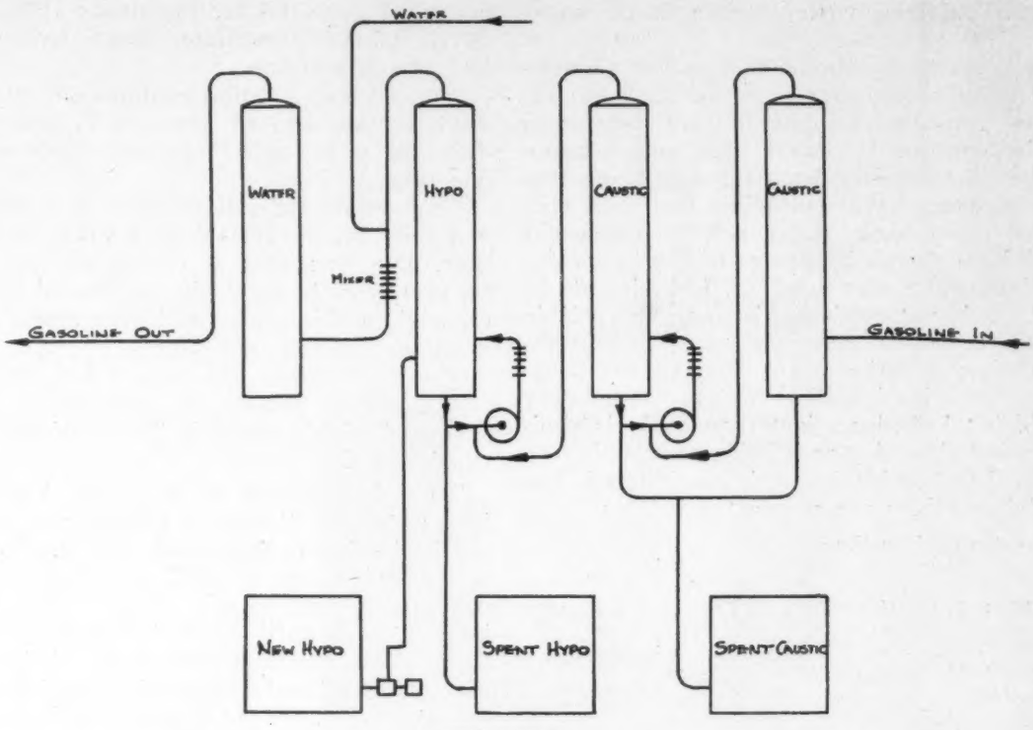


FIGURE 2

A simple continuous hypochlorite treating system

canted to another tank or used directly. The sludge and excess lime remaining in the tank will not interfere with subsequent batches until an appreciable amount has accumulated, at which time the tank should be cleaned by flushing out the sludge.

As stated previously, a level of 18 inches or greater must be maintained above the chlorine inlets to obtain efficient results, however no special inlet spiders or distribution heads are necessary. For a 1000-gallon batch, two half-inch iron or lead pipes extending nearly to the bottom of the expansion tank from a common header will carry the chlorine easily and give no chlorine evolution from the alkali providing the inlet rate is reasonable. Some sort of pressure-equalizing header should be used and the downcomers should all be of the same length so that equal heads of liquid will be maintained on each inlet.

In the choice of the alkali for the hypochlorite several factors have to be considered, among those are cost, availability, ease of handling, available or potentially available equipment, applicability of a particular hypochlorite to the products to be treated and disposal of the residual products. As far as cost is concerned calcium hypochlorite is the cheapest. On the basis of present chemical prices the cost per pounds of available chlorine as calcium hypochlorite is 3.73 cents. Against this cost advantage must be balanced such factors as increased labor cost to prepare, disposal of insoluble lime sludge, and a slightly greater tendency to form emulsions with products to be treated. The last disadvantage is more pronounced when treating the heavier petroleum distillates such as insecticides and kerosene.

Figured on the same basis as above, the cost per pound of available Cl in the form of NaOCl prepared from NaOH is 5.82 cents and the cost when prepared from soda ash 5.30 cents. It seems that the difference in cost between the latter two would not justify the selection of soda ash as the alkali unless some special advantage not taken into consideration here was obtained.

BLEACHING POWDER

In the above preparations of hypochlorites no mention has been made of the direct use of bleaching powder. The main consideration was the primary manufacture of the hypochlorite from the elementary constituents. Bleaching powder ranging in available chlorine content from 30 to 65 percent may be used as the source of oxidizing power by bleaching out the active constituent with water and then proceeding exactly as outlined for settled calcium hypochlorite. Some refiners prefer to use the bleaching powder as a slurry while others let the solution settle and decant the clear supernatant hypochlorite.

In the past, various claims have been made for the powers of hypochlorite, some valid and others rather fantastic. As a speedy, clean, sweetening reagent it is without peer, but there are some petroleum products on which it must not be used if satisfaction is expected. Hypochlorite is very satisfactory when used on H_2S free natural gasolines, all straight-run distillates relatively free from olefins and aromatics, and some refinery recovery gasolines depending on the unsaturate content of same. A decision to use hypochlorite should not be made until complete laboratory tests have been run to determine its applicability to the product at hand. To the author's knowledge, it makes no difference how sour the product is, hypochlorite will sweeten it if sufficient oxidizing power is kept in contact with the oil. And it might be added here that the

utilization of the available chlorine is very complete, only a trace of oxidizing power remains in the spent solution.

It has been stated by Birch[1] that sulfur, in mercaptan and other organic forms is oxidized and removed to a considerable extent from petroleum distillates by continued contact with active hypochlorite. The time required was stated as being two hours. It was claimed that sulfoxides, sulfones, etc., were formed which were water soluble and could be removed from the oil by means of the hypochlorite and subsequent water washing. Experiments in this laboratory do not confirm this to an appreciable degree. If the reactions were complete, the time required for their completion is not economically feasible in a commercial installation. The sweetening reaction which takes places instantaneously is similar to that effected by doctor treating except that no sulfur is added and no blackstrap is precipitated. The two essential reactions are contrasted below:

Plumbite Sweetening Reactions:

$$PbO + 2RSH \rightarrow H_2O + Pb(RS)_2$$

Lead Oxide — Mercaptan — Lead Mercaptide

$$Pb(RS)_2 + S \rightarrow PbS\downarrow + (RS)_2$$

Lead Mercaptide — Organic Disulfide

Hypochlorite Sweetening Reaction:

$$NaOCl + RSH \rightarrow NaCl + H_2O + (RS)_2$$

Hypochlorite — Mercaptan — Organic Disulfide

It will be seen that sweetening is done by the oxygen of the hypochlorite in uniting two molecules of mercaptan sulfur and eliminating hydrogen therefrom. The organic sulfide is preferentially soluble in the oil phase and thus no actual reduction in sulfur content is obtained by the mere sweetening reaction itself. In an oil originally containing free or elementary sulfur the hypochlorite is at a disadvantage when compared with plumbite in that the plumbite will utilize the dissolved sulfur to aid its reaction, whereas the hypochlorite has no utility for it. The original sulfur in an oil treated with doctor solution merely effects a reduction in the amount necessary to "break" out the lead mercaptide as the sulfide.

Hypochlorite treating requires a minimum of skilled attention and laboratory control. A given batch will sweeten until its available oxidizing power is depleted and then it becomes merely a weak solution of sodium or calcium chloride and dilute alkali. There is no sludge to dispose of or revivify and no loss of treated product due to emulsions.

After a batch of hypochlorite is made it is customary to have the laboratory check the available chlorine. This may be done accurately by a titration method, which consists of liberating iodine from a potassium iodide sodium acetate solution and then titrating the liberated iodine with standard sodium thiosulfate solution, using starch as an indicator. The solutions required are: "red lead solution," (as described in A.S.T.M. Standards 1933, Part II, p. 564), sodium thiosulfate, dilute hydrochloric acid and starch solution.

The red lead solution contains 600 grams C.P. sodium acetate and 48 grams C.P. potassium iodide dissolved in enough 25 percent acetic acid to make one liter.

The sodium thiosulfate solution is made .355 normal and contains 90.3465 grams reagent $Na_2S_2O_3$ per liter. The normality is chosen so that when a 10 cc. sample of hypochlorite is titrated the reading in cc. sodium thiosulfate will give directly the grams available chlorine per liter.

The hydrochloric acid is a 1:1 solution.

The starch solution is made up by dissolving 4 grams of soluble starch in 500 cc. of near-boiling distilled water.

To make the test, 10 cc. of the hypo is pipetted into a 500 cc. Erlenmeyer flask and 15 cc. of the red lead solution are added. 100 cc. of cool distilled water and 10 cc. of HCl are then added and the contents swirled to mix. The $Na_2S_2O_3$ is then run into the flask until the dark brown color is reduced to a yellow at which point 5 cc. of the starch solution are added and the titration continued to a colorless end point. Should a sample of hypochlorite containing more than 10-12 grams per liter Cl be run by this method more red lead and HCl will be necessary for the completion of the reactions. Sunlight decomposes the red lead solution, liberating the iodine, thus it should be kept in amber bottles. The number of cc. of sodium thiosulfate required to complete the titration is directly the grams per liter chlorine in the hypochlorite.

DETERMINING COSTS

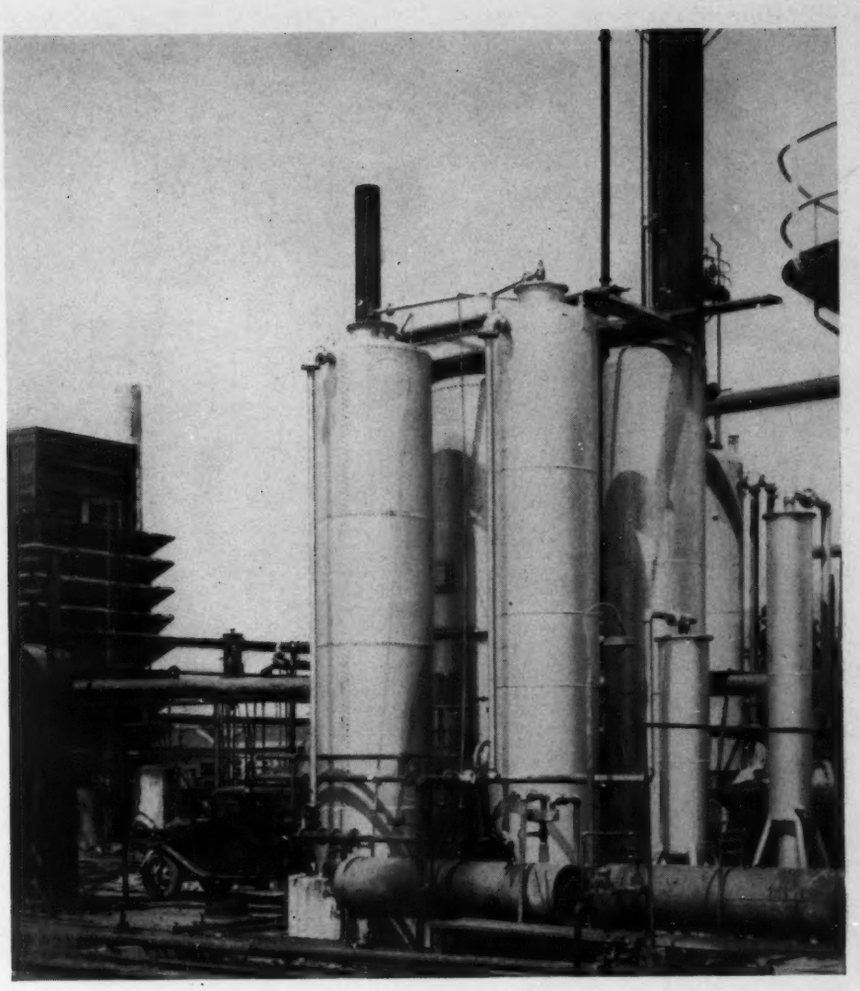
It is a relatively simple matter to determine the chlorine consumption and hence the cost of treating any given petroleum distillate. It is only necessary to treat a known quantity of distillate with a known quantity of hypochlorite and knowing the Cl content before and after the treatment, the consumption and the cost are easily calculated.

Example: Assume that a liter of gasoline was sweetened with 200 cc. of hypochlorite having an available Cl content of 10 grams per liter. After using, the hypochlorite tested 4 grams per liter; thus 6 grams Cl per liter of treating solution were used or 6 times 200 cc./1000 cc. grams were required to sweeten one liter of gasoline. If 1.2 grams Cl were required per liter of gasoline then

$$\frac{1.2 \times 3.785 \times 42}{454}$$

or .42 pounds Cl are required per barrel. With this .42 pounds Cl are also consumed (.42) (80/71) .473 pounds NaOH, or equivalent weight of calcium hydroxide. The cost then for chemicals at current prices would be (.42) (3.1) + (.473) (2.4) or 2.48 cents per barrel of gasoline. The example shown is typical of a very sour product and a corresponding reduction in cost will accompany a sweeter distillate. An average figure for typical Mid-Continent distillates, using Na hypochlorite is in the neighborhood of 1 to 1½ cents per barrel. Using calcium hypochlorite the cost would be cut about 36 percent or to approximately ¾-cent per barrel treated.

[1]Hypochlorite Process in Refg., O. & G. J. May 23, 1929, p. 190.



Typical treating plant

Continuous Treating Plant Design

R. T. HOWES *and*
CHAS. N. WHITAKER,
Consulting Engineers

THE refiner has passed through various stages of trials and tribulations in an endeavor to develop an efficient method to treat naphtha and pressure distillate. It is understood that the treatment of other petroleum products may be included, but the writers wish to confine this article to the treatment of naphtha and pressure distillate.

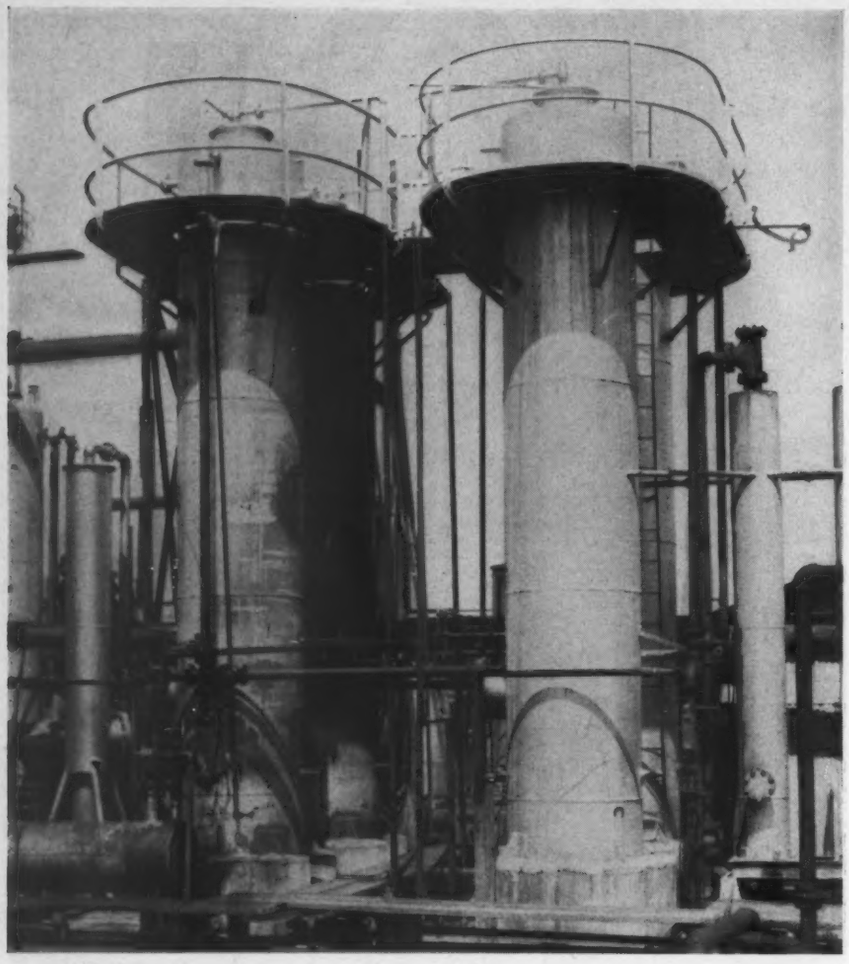
The various methods have been,

1. Agitator with air agitation and water wash.
2. Agitator with circulation system.
3. Continuous treating through horizontal or vertical tanks with baffles, and contact through orifice plates.
4. Continuous treating through towers packed with rock fragments, tile rings, etc.
5. Sludge separation by centrifuge.

The objections to the above may be one or more of the following,

1. High losses.
2. Excessive chemical consumption.
3. Inefficient desludging.
4. Water washing.
5. High initial plant cost.
6. Disintegration of tower packing.
7. Fire hazard.
8. Loss of time by batch process.
9. Large space required for equipment.

The one step of water washing requires lead-lined equipment with resultant high installation cost, or without the protection of lead lining, high maintenance costs may be anticipated because of corrosion. Scarcity of water in some localities causes more diffi-



Naphtha treating unit, capacity 3,000 barrels per day

culty, and disposal of the wash water in well settled communities is still another problem. Water washing may cause color revision.

Elaborate charts are available for the calculation of orifice plates for the mixing of oil and chemicals, but the objection to this method is that the rate of treating must be constant to obtain desired results.

With these objections in mind, the writers have given considerable time to experiment with specially packed towers, and to plant design to obtain a satisfactory system of low initial plant cost, and low operating cost. The special packing has the property of acid wetting in preference to the oil, and will remove moisture from the oil after caustic neutralization. This packing will not deteriorate and steam may be used for cleaning.

Viscosity, gravity, and rate of oil flow will indicate the treating tower diameter. Height of tower is also important. The treating vessels as shown in flow sheet are vertical towers. This arrangement was selected because of small space requirement, and better operating results. Efficiency of contact and sludge removal reduce chemical consumption to the minimum. Throughput rate may be varied without reduction in efficiency. The quantity of acid sludge in the oil leaving the desludging tower will average 15 mg per liter when treating naphtha, and 35 to 60 mg per liter when treating pressure distillate.

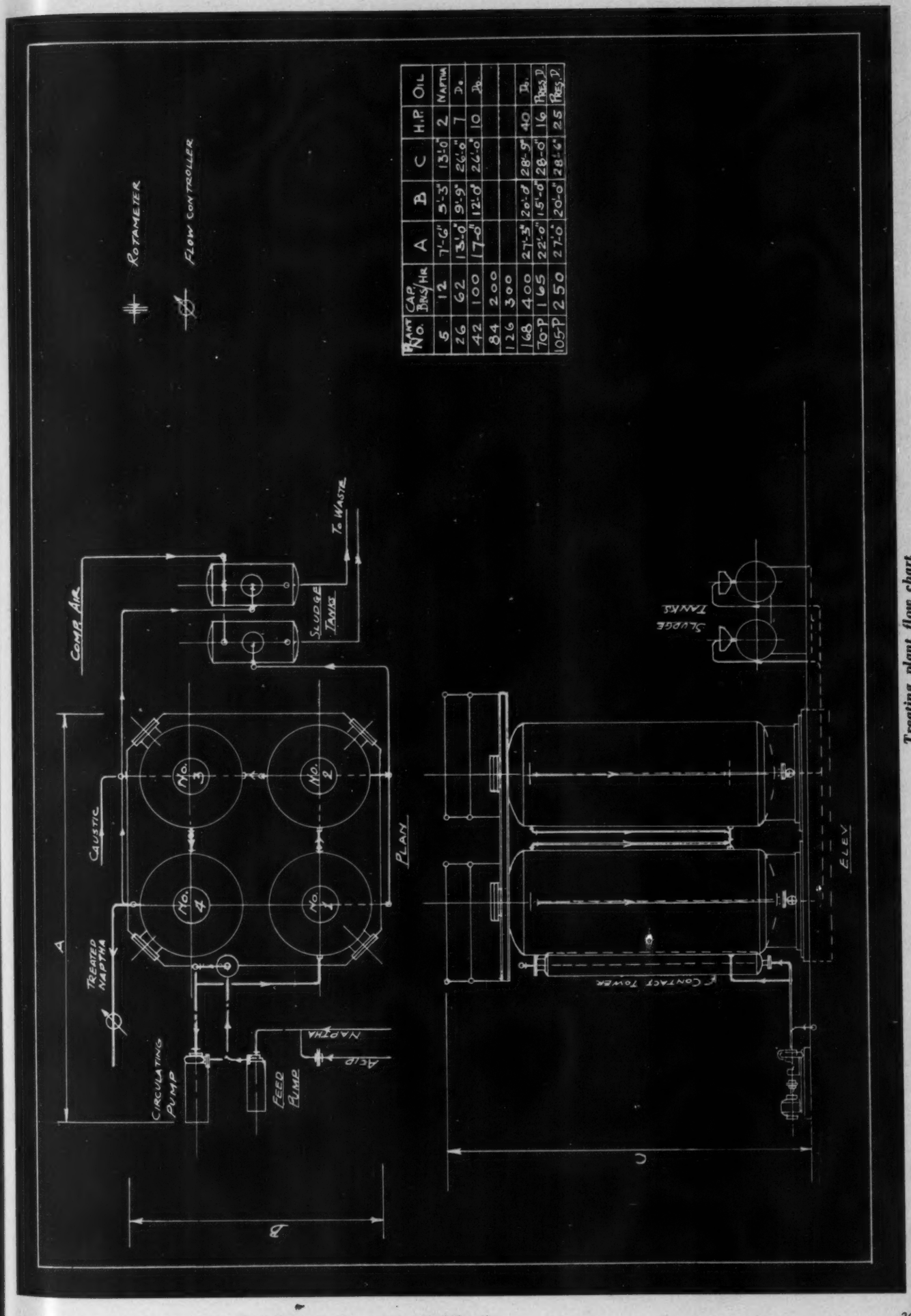
The plant equipment is essentially a contact tower of small diameter, and four towers of larger diameter in series. The oil is circulated by means of a low head centrifugal pump, at velocity sufficient to obtain efficient contact in the contact tower. A feed pump discharges into the contact tower in parallel with above circulating pump. Part of the flow from the contact tower, equivalent to the desired treating rate, is diverted to the No. 1 tower. No. 1 and 2 towers are desludgers from which sludge may be drained once every 24 or 48 hours without interruption of operation. Low gravity caustic solution is pumped by batch into No. 3 tower for neutralizing the oil from No. 2 tower. The caustic is tested at regular intervals and is replaced about once weekly. The spent caustic and acid sludge can be easily drained to blow tanks for disposal. No. 4 tower is a reserve to remove moisture after caustic neutralization.

The towers are so designed that as the finely divided sludge and oil move upward, the sludge accumulates on the special packing to form droplets heavy enough to settle to the tower bottoms countercurrent to the oil stream. The treating rate may be maintained constant by means of an automatic flow controller. Centrifugal pumps are preferred. Fresh acid at constant rate is introduced into the feed pump suction. A rotameter is recommended for gauging the rate of acid flow.

Sludge or caustic which may accumulate on the tower packing after a long period of operation is easily removed by the introduction of steam for four to six hours.

Water wash is not required. Hence, maintenance cost is low. Plants with a capacity as high as 15,000 barrels per day are operated by the refinery pumper, or gauger.

Compared with agitator treating, acid consumption has been reduced as much as 60 percent, and caustic consumed has been reduced to .025 pounds per barrel treated.



PLANT No.	CAP. BRLS/HR	A	B	C	H.P.	OIL
5	12	7'-6"	5'-3"	13'-0"	2	NAPTHA
26	62	13'-0"	9'-9"	26'-0"	7	Do.
42	100	17'-0"	12'-0"	26'-0"	10	Do.
84	200					
126	300					
168	400	27'-3"	20'-0"	28'-9"	40	Do.
70-P	165	22'-0"	15'-0"	28'-0"	16	Pres. D.
105-P	250	27'-0"	20'-0"	28'-6"	25	Pres. D.

Treating plant flow chart

Measurement of Viscous Fluids

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School of Mechanical Engineering,
The University of Oklahoma

THE orifice meter, of the sharp square-edged type has proven itself beyond question admirably suited to the measurement of gases and non-viscous liquids. Although the coefficient of discharge for an orifice meter is variable, being a function of Reynolds' number, the variation is so small that the coefficient in the non-viscous region is substantially a constant. The actual variation is within the limits of accuracy of commercial measurement.

With fluids of higher viscosity, however, the degree of variation increases. In the measurement of viscous fluids with square-edged orifices, it is possible to have a 10 percent change in coefficient caused by the viscosity change produced by changes in temperature, which occur during a change in the process. This variation of the coefficient of discharge has caused many engineers, with some degree of justification, to refrain from using the orifice meter on viscous fluids. Unless the fluid viscosity has been definitely determined for the entire range of operating temperatures and unless the fluid temperature at metering conditions is definitely known, it is impossible to determine the proper orifice coefficient.

In the effort to develop an orifice meter for viscous fluids with a substantially constant coefficient of discharge the round-edged orifice was investigated. Coefficient curves characteristic of a nozzle and of a conventional square-edged orifice are shown in Figure 1. It will be noted that in the region of most commercial measurement work; with Reynold's numbers above 1000; the nozzle coefficient increases and the square-edged orifice coefficient decreases with increase in Reynolds' number. It is logical to assume that the coefficients applicable to a round-edged orifice would be represented by a curve somewhere between the nozzle and the square-edged orifice. If the proper edge could be determined, an orifice could be produced that would have a substantially constant coefficient. With such an orifice, accurate flow calculations could be made without correcting for the infinite factor—viscosity.

With this in mind, the author conducted a program of research in the laboratories of a large meter manufacturer, to determine the proper edge to produce the desirable flat coefficient characteristic. Based upon the results of this work, a series of orifice plates were produced in which the desired results were substantially accomplished. In Figure 2 the results of tests on a typical round-edged orifice are shown together with the results of tests on the same size of conventional orifice with a sharp square edge. It will be noted that in the ordinary commercial range of fluid measurement; with Reynolds' numbers above 1000, the coefficient of discharge for the round-edged orifice is substantially constant at 0.855. The fluid used in the test work was molasses in various degrees of dilution with water. With this fluid, testing over an extremely wide range of viscosities was possible.

Gratified by the results of these tests, the author

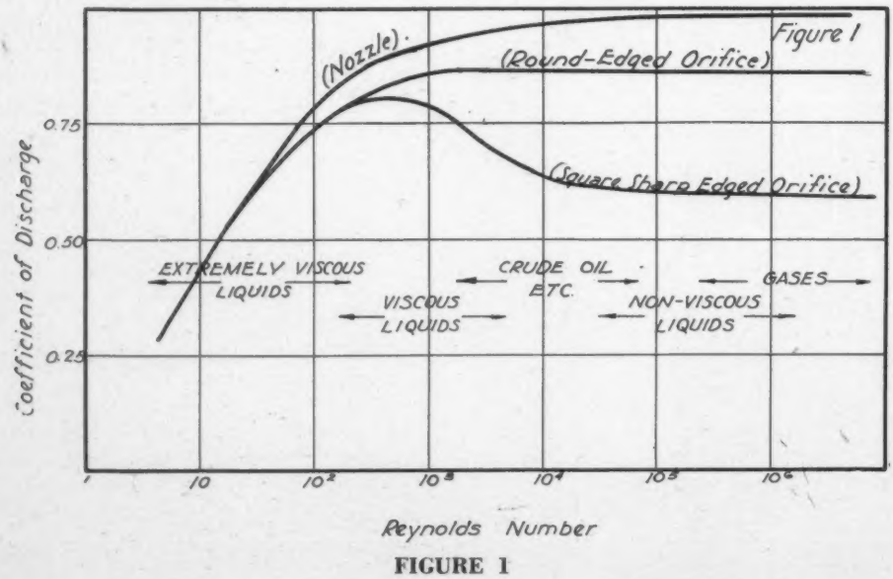


FIGURE 1

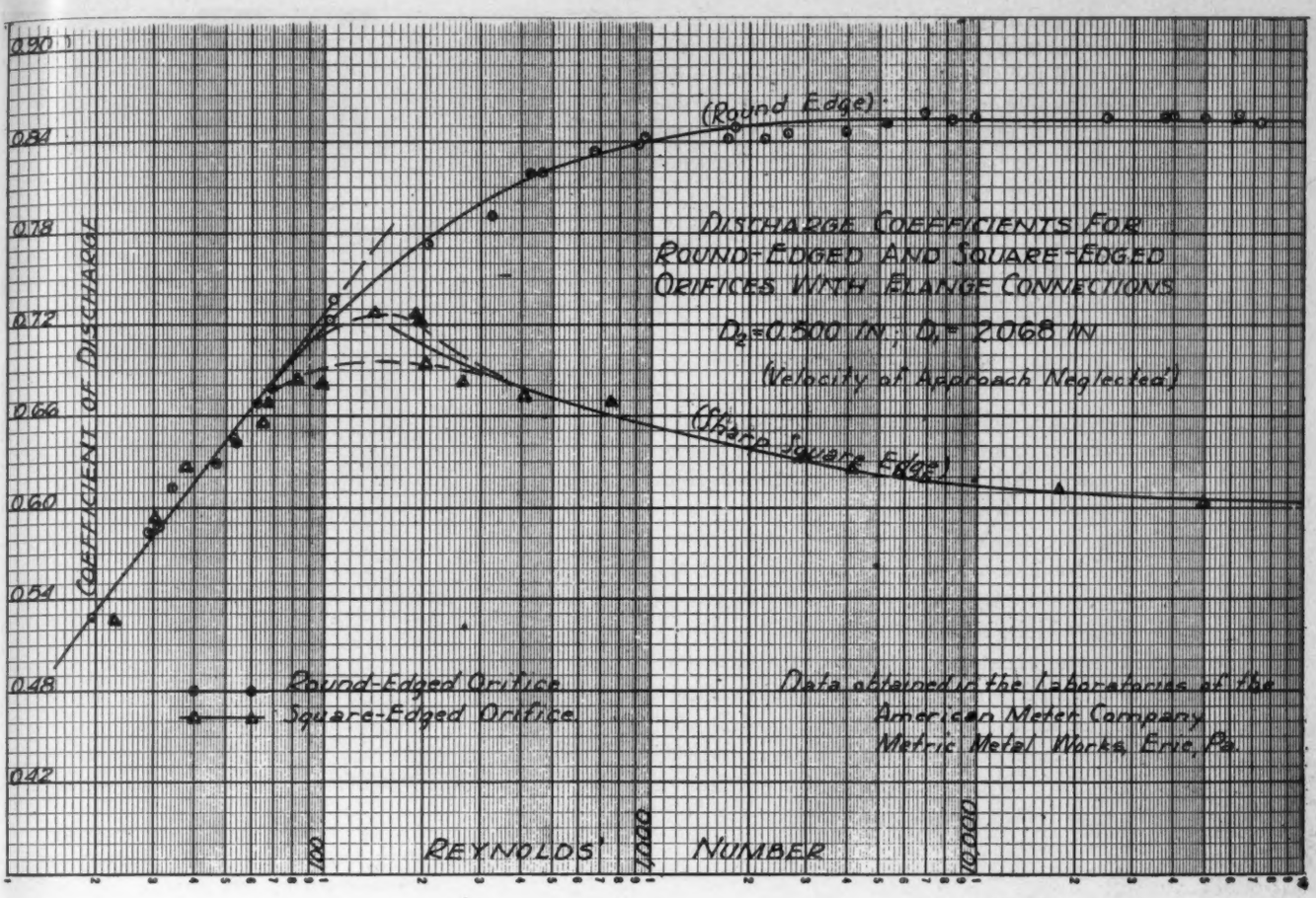


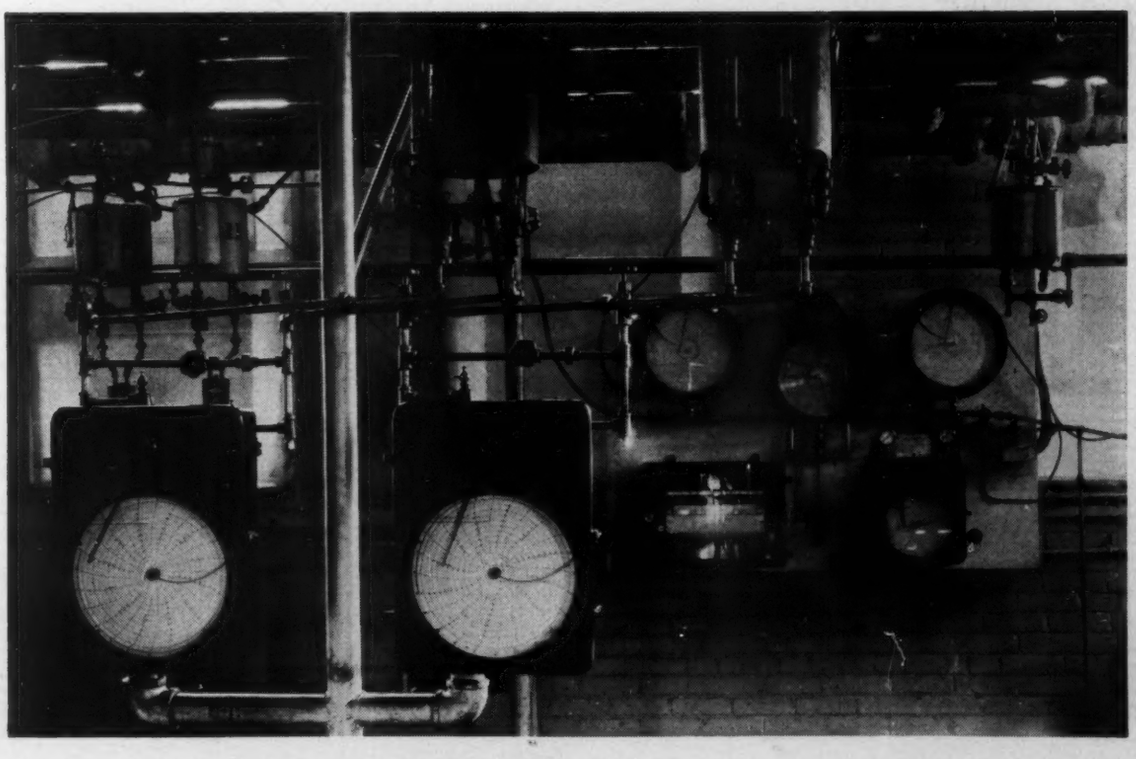
FIGURE 2

continued the investigation on the 4-inch line in the Fluid Meters Laboratory at the University of Oklahoma. With the apparatus available in this laboratory, accurate determinations could be made on rates of flow as high as 750 barrels per hour. The fluid used in this case was an oil, the viscosity and density of which had been carefully determined over a wide temperature range.

In order to duplicate field conditions, still retaining the controlled conditions of the laboratory, two

FIGURE 3

View of recording meters and test apparatus used in investigation.



calibrated recording differential pressure meters having one-hour clocks were installed. One of these meters was to be used for the differential obtained with flange taps and the other for the differential on the same orifice obtained with the pipe taps. These meters together with the separating chambers between them and the test line are shown in Figure 3. The two-story tank used for the storage and measurement of the test fluid is shown in Figure 4. In this tank the upper and lower chambers each have a capacity of approximately 90 barrels.

The results obtained in the continuation of the investigation at The University of Oklahoma corroborated the results previously obtained in the tests on the two-inch line. Of the coefficient characteristics for the various edge forms investigated, those which most closely indicated a constant coefficient of discharge are shown in Figure 5.

Although the investigation is yet incomplete, the results obtained to date are sufficient to warrant the statement that round-edge orifices may be produced with coefficients which, within the limits of accuracy of commercial measurements, are substantially constant. With orifices of this type, the need for constant observation of the fluid temperature and for frequent sampling of the fluid for viscosity determinations would be eliminated. The orifice with the coefficient determined at the factory could be used in the field without corrections.

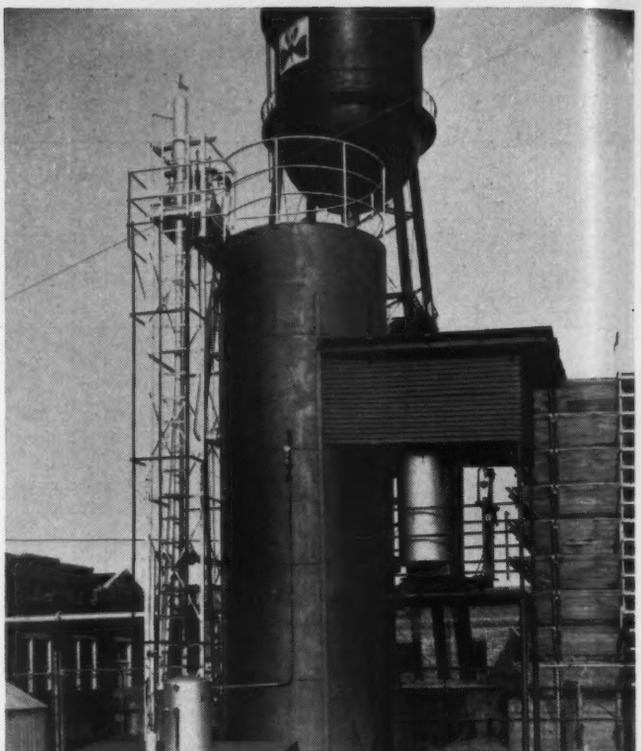
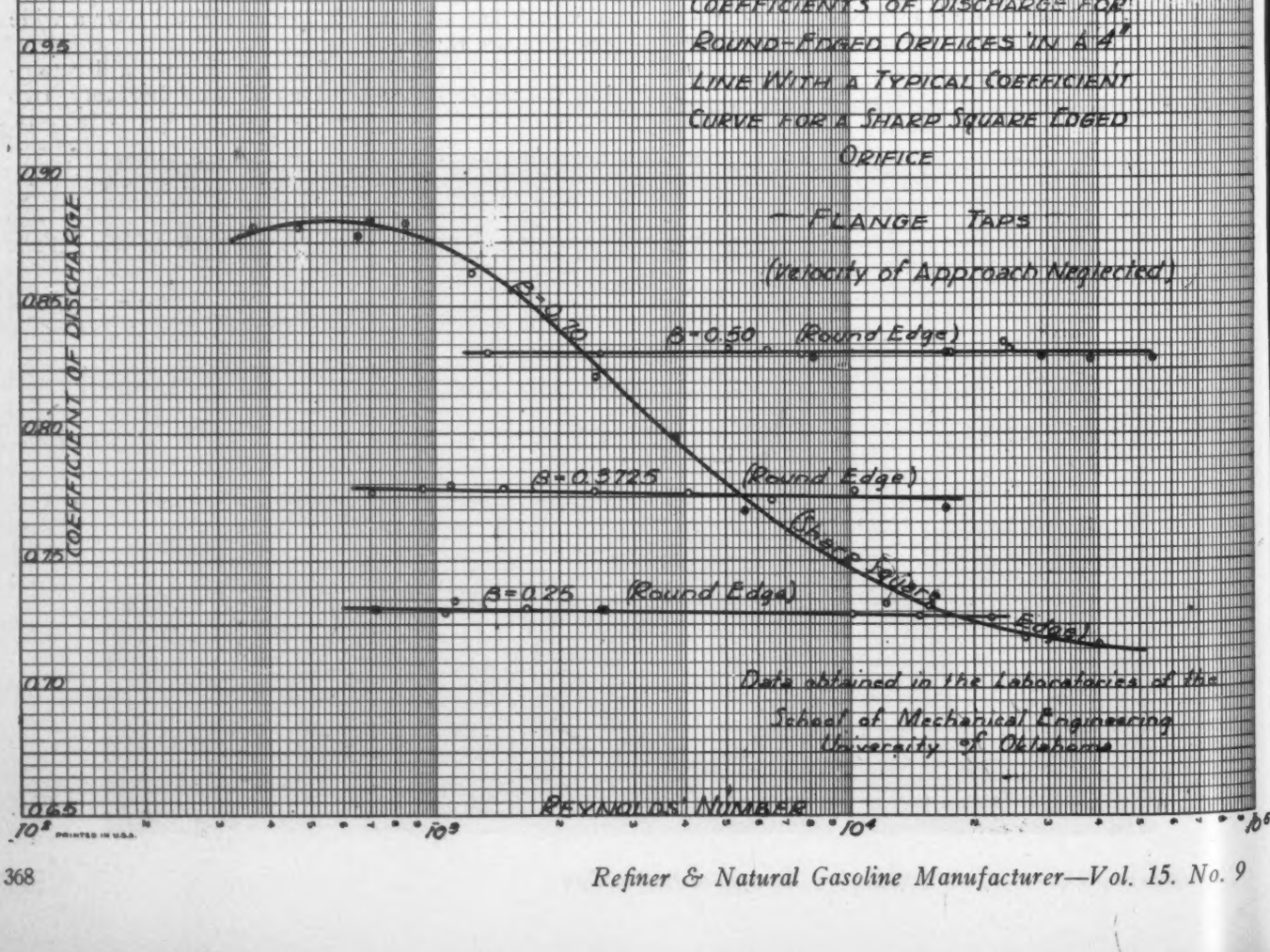


FIGURE 4

Showing two-story test tank used for storage and measurement of test fluid.

FIGURE 5



Vacuum Distillation

Operation of Asphalt Unit

IN order to increase the output of asphalt products manufactured from heavy Arkansas crude, Lion Oil Refining Company designed and erected a vacuum distillation and reduction unit in the spring of 1936, at its Eldorado plant. Products made through this unit are, gasoline, tractor distillate, gas-oil, lubricating oil distillate and asphalt flux.

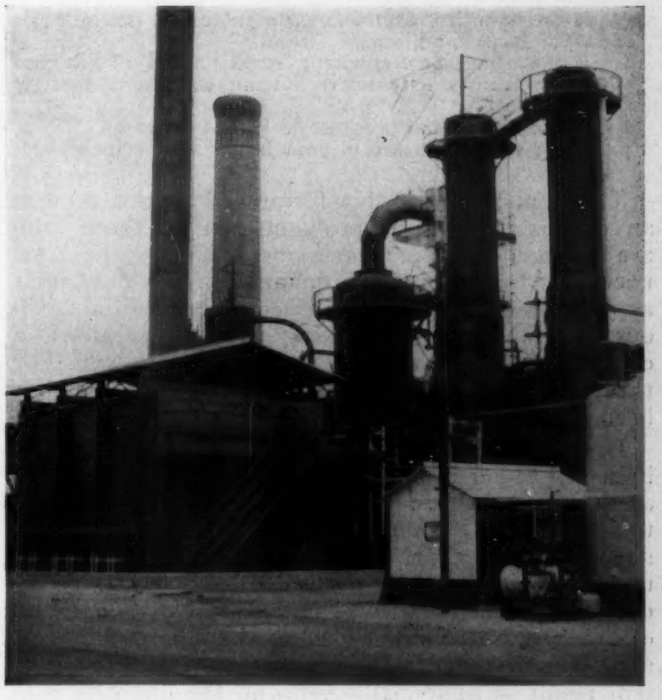
Heavy Arkansas crude, 19° A.P.I., is the raw material used. It carries a small percentage of gasoline but a large amount of asphalts, which are said to be comparable to Mexican asphalt in all characteristics. To reduce this heavy crude to the products desired without excessive heat, vacuum is used to accelerate distillation and separation of lighter cuts from the heavy asphalt fluxes.

Approximately 2500 barrels of this crude is charged daily to the unit. One of the peculiarities of this oil is the amount of crystaline salt carried in it, which has been difficult to separate. This substance has caused considerable chloride corrosion in the condensing sections, as well as a deposit on the tubes and other parts of the system. Prior to the time when the salt problem was solved by electrical dehydration the crude carried an average of 140 grams of crystaline salt per barrel of oil.

The crude charge, after passing through the salt eliminating equipment, enters a surge drum at a temperature of about 140°F., and is picked up by the crude-charge pump and delivered to the heater. Tubes for the first contact with furnace heat are in the convection section of the furnace, being 3¼ inches I.D. and 4 inches O.D., 30 feet in length, the outlet of which carries a temperature of 230°F. This bank is connected to a transfer line leading to the primary fractionating column, 7 feet in diameter by 40 feet high, where the small amount of gasoline is removed overhead. Bottoms from the column are again picked up by a pump and re-enter the furnace in the second pass for additional heating.

The heat imposed upon the oil in this phase of distillation is controlled so that the temperature never rises above 700°F. Upon passage through the secondary heating tubes, the oil is transferred to the secondary fractionating column where an overhead stream of tractor distillate is removed, as well as a side stream of gas oil. Approximately atmospheric pressure is maintained upon this column, with the bottoms removed by pumping so that the stripped heavy stock may re-enter the heater for the third pass. The upper two rows of convection tubes, containing 12 tubes, are so arranged that the temperature is raised to about 710°F.

The heated oil, containing the asphalt and the lube distillate, is transferred at 710°F. to the vacuum column for final reduction. Overhead fractions are condensed in a 1200-square foot tubular condenser, which carries the lube oil vapors and uncondensable gases. Equipment was installed on this column to maintain an average of 26 inches of vacuum, mercury measurement, in order that all of the lighter fractions not desired in the final bottom product could be removed. The top of the vacuum column has an average temperature of 650°F., while the bottom carries about 635°F.



Lion Oil Company's asphalt plant, Eldorado, Arkansas

The bottoms, consisting of about 45 percent of the original charge, are removed from the base of the vacuum column with a steam turbine-driven turbo-centrifugal two-stage pump and discharged through tubular exchangers to reduce the temperature sufficiently that it may be safely stored for future processing, or shipped. Sufficient automatic controls are used in this plant to regulate the temperature and volume of charge so that any grade of finished asphalts, fluxes and road oils may be manufactured.

An Alignment Chart *for Measurement of Gas with the Orifice Meter*

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School of Mechanical Engineering, the University of Oklahoma

IN the measurement of natural gas, it is common practice to express the flow in cubic feet per hour, or day, referred to some specific reference or base condition of pressure and temperature. The calculation of the quantity of gas flowing is made by the use of the formula:

$$Q_h = C' \sqrt{h_w p_f}$$

Where,

Q_h, is the quantity rate of flow, in cubic feet per hour, or day at base conditions.
C', is the orifice flow constant, consisting of all the conversion factors to convert flowing conditions to base conditions.
h_w, is the differential pressure in inches of water.
p_f, is the static pressure in pounds per square inch absolute.

The application of this formula does not present an extremely difficult problem, but to those who are engaged in the measurement of gas the time necessary to compute the quantity of gas flowing is appreciable. For the field engineer, who is often without the facilities for making such calculations, a chart of this type serves the purpose quite well. For these reasons an alignment chart of this formula has been constructed.

In the use of an alignment chart to solve formulae it is well to keep in mind their disadvantages as well as their advantages. The accuracy of the results obtained will, of course, depend largely upon the person using the chart and the accuracy of the data used. In this chart the portion subject to the greatest possible error will be found at the lower end of the scale of the extension and the differential pressure. Small errors in locating points on these scales will result in appreciable error in the quantity rate of flow. This should be kept in mind when drawing lines from one scale to another. However, it is seldom that the basic data is observed with a greater degree of accuracy than can be obtained with the chart. Consequently, the accuracy limitations are usually negligible.

To proceed with the solution of a typical problem in which the flow formula would be used, let it be assumed that the result desired shall be the quantity rate of flow in cubic feet per hour. The static pressure, differential pressure, and the orifice flow constant are usually the known quantities when the flow rate is to be computed. It is first necessary to correct the static pressure to absolute static pressure. This is done in one operation on the chart by merely locating the gage pressure on the right side of the scale; the absolute static pressure is plotted on the other side of the same scale. From this point, draw a straight lime to a point on the differential pressure scale corresponding to the observed differential in inches of water. This line wll intersect the scale of the extenson

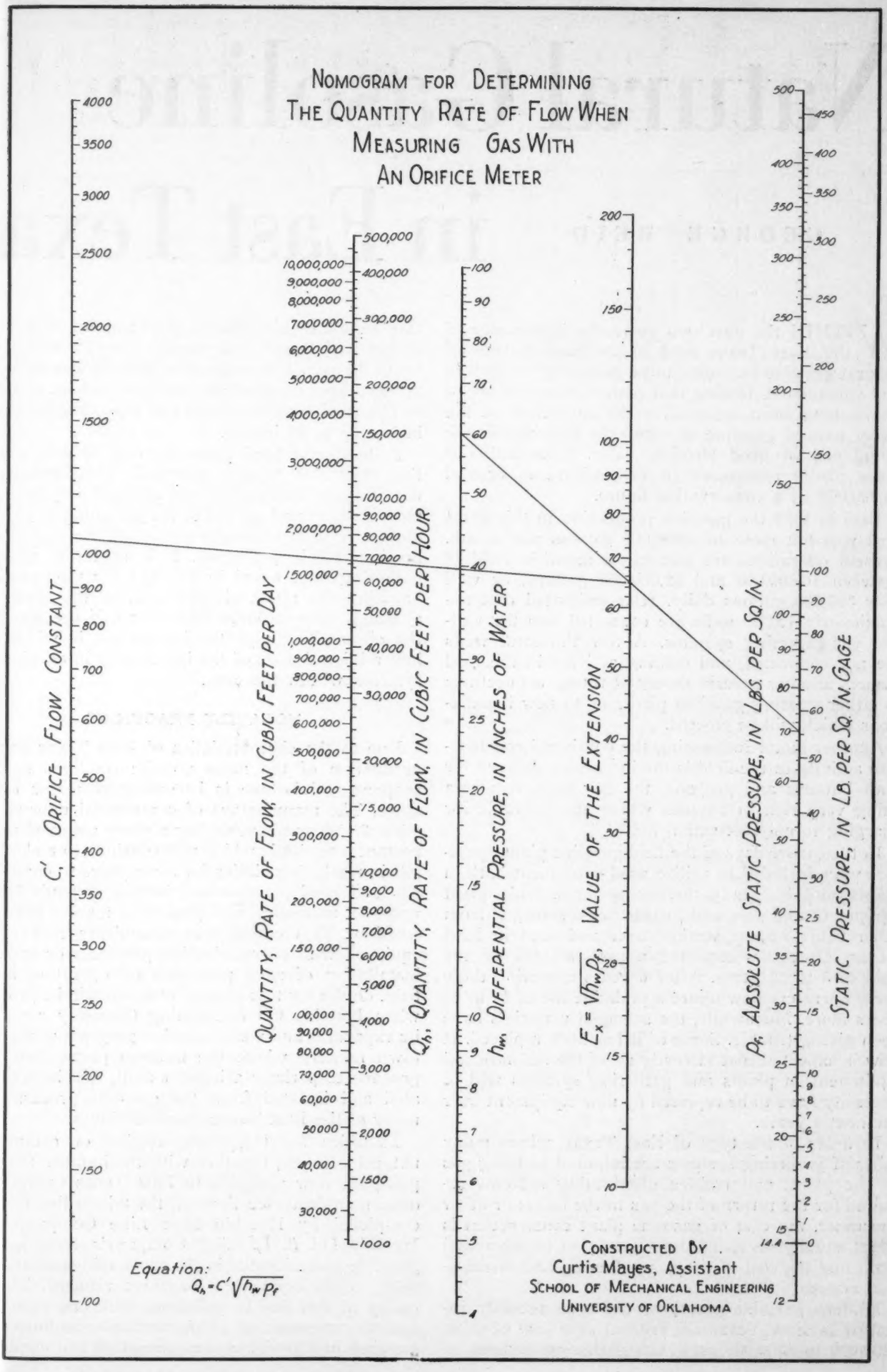
$$\left(E_x = \sqrt{h_w P_f}\right)$$

and its value may be read directly. Next, draw a straight line from the extension to the orifice flow constant applicable to the conditions of measurement and read the result at the intersection of this line with the quantity rate or flow scale. The daily rate of flow may be observed by noting the point of intersection of the second straight line with the coincident daily flow scale.

When orifice meters are employed to measure the flow of gas, care must be exercised to keep the differential pressure high enough to enable one to read it with a fairly high degree of accuracy. When the differential pressure is low, there may be an appreciable error in the calculated flow, due to the fact that a small error in reading the meter chart might be an appreciable percentage of the total differential. An alignment chart may be used to an advantage in this connection. The field engineer can take the quantity calculated from the data obtained and work back to find the proper orifice flow constant and, consequently, the right size orifice to give a higher differential pressure, which would in turn give a more accurate indication of the quantity rate of flow. This may be done as follows:

After calculating the flow as accurately as the low differential pressure will permit, locate this value on the scale Q_h. Then, from this point, draw a line to a point on the extension scale such that, when a line is drawn from the static pressure scale through this predetermined point on the extension, a differential pressure will be indicated, that will result in a more accurate indication of the flow. Now extend the line drawn from Q_h to E_x on to the C' scale where the new orifice flow constant will now be found. This constant may now be looked up in a handbook and the orifice, whose constant will most closely check this value, should be inserted in the line.

It is obvious that any one of the variables of an equation may be solved by mere mathematical manipulation. In solving equations by use of alignment charts, any one of the variables may be solved by beginning at different points on the chart. Ease of use and the application of these charts become more apparent as familiarity with them is developed.


NOMOGRAM FOR DETERMINING
THE QUANTITY RATE OF FLOW WHEN
MEASURING GAS WITH
AN ORIFICE METER
C', ORIFICE FLOW CONSTANT
QUANTITY, RATE OF FLOW, IN CUBIC FEET PER DAY
Q_h, QUANTITY, RATE OF FLOW, IN CUBIC FEET PER HOUR
h_w, DIFFERENTIAL PRESSURE, IN INCHES OF WATER
E_x = √(h_w P_f), VALUE OF THE EXTENSION
P_f, ABSOLUTE STATIC PRESSURE, IN LBS. PER SQ. IN.
STATIC PRESSURE, IN LB. PER SQ. IN. GAGE
Equation:
Q_h = C' √(h_w P_f)
CONSTRUCTED BY
Curtis Mayes, Assistant
SCHOOL OF MECHANICAL ENGINEERING
UNIVERSITY OF OKLAHOMA

Natural Gasoline in East Texas

GEORGE REID

WITHIN the past two years the importance of the East Texas field in the manufacture of natural gasoline has come to be generally recognized and appreciated. During that period about a score of plants have been erected for the extraction of the sweet natural gasoline of relatively high anti-knock rating and of good blending value. Construction of these plants represents an expenditure of around $6,000,000 as a conservative figure.

Late in 1933 the gasoline production in this great area was but close to 2,000,000 gallons per month. Present operations are securing a monthly yield of between 10,000,000 and 12,000,000 gallons, or well over 300,000 gallons daily. It is estimated that approximately 15,000 wells are connected into the various gas-gathering systems. A few thousand wells are not connected, and drilling activity in the field assures another several thousand future connections to either existing gasoline plants or to new installations which will be erected.

Another factor influencing the continued construction activity in the field is the increasing demand for both butanes and propane, the gas from this area being very rich in butanes which are desirable for charging to polymerization units.

In the earlier days of the field gasoline plant operators were included to utilize used equipment both in plants and in gas gathering systems. This plant equipment and pipe and fittings were salvaged from other fields, hastily worked over and used in East Texas. Operators expected a probable life of the field of 5 to 10 years. After 6 years operation there these operators now figure a probable life of 15 to 25 years more. Meanwhile, the salvaged materials have been giving trouble. Some of it has been replaced. It now is expected that virtually all of the second-hand equipment in plants and gathering systems will of necessity have to be replaced by new equipment over the next 5 years.

In fields of the type of East Texas, where many miles of gathering systems are required to bring gas to the plant, and residue distributing systems required for the return of the gas to the leases or other consumer, the cost of gasoline plant construction is about equally divided between the cost of the actual plant and the cost of the gas gathering and distribution system.

Modern gasoline plants of the type recently installed in East Texas are erected at a cost of from $200,000 to $300,000 each. Gas-gathering systems in this section require pipe in sizes ranging from 2 to 4 inches, with larger lines ranging from 10- and 12-inch up to 20-inch. It is estimated that the gas-gathering systems have involved the laying of at least 500 miles of 2-inch pipe and 715 miles of pipe ranging from 4 inches up to 20 inches.

Estimates at hand place the cost of well connection from $200 to $250 per well. This involves the use of about 1500 meters and as many regulators for measurement and control of the gas going to gasoline plants. With 15,000 wells connected the cost of connections totals $3,000,000. It is said that the gas-gathering lines equal in tonnage the pipe used for handling the crude oil produced in this field, and although they measure just over half the length of the oil-handling pipe the investment is within one half million dollars of the investment in oil pipe line systems within the area.

VOLATILE FRACTIONS

Due to the characteristics of East Texas gas the production of the more volatile fractions such as propane and butane is becoming of major importance. The manufacture of commercial natural gasoline, 26/70 and heavier, has already assumed an important magnitude which will continue to make itself felt in marketing circles for some years to come. The production of propane and butane depends largely upon an accessible and profitable market for these fractions. This market is to come either from refiners equipped with polymerization processes or from the installation of such processes by operators in the field. Outlet for this class of material will be provided when Humble Oil & Refining Company completes its expansion and modernization program at the Baytown refinery where the butanes particularly, and propane to perhaps a lesser extent, will be fractionated and isolated from the gasoline processed by many of the East Texas gasoline plants.

Facilities for the transportation of commercial natural gasoline, together with the butanes and propane, are now available to East Texas natural gasoline manufacturers through the 8-inch line recently completed by Humble Pipe Line Company from Humble Oil & Refining Company's New London gasoline plant, located in the south mid-section of the field, to the company's Baytown refinery. The capacity of this line is sufficient, with one pump station, to transport all of the natural gasoline manufactured in East Texas at present. When conditions

are such that the butanes and propane are required for charging the new polymerization plant, it is thought that additional pump stations will be erected to permit handling of much larger quantities of these products. A large portion of the gasoline now produced in East Texas will be shipped through this pipe line without stabilization in the field, it is said, and such natural gasoline may have a vapor pressure of approximately 55 pounds, Reid.

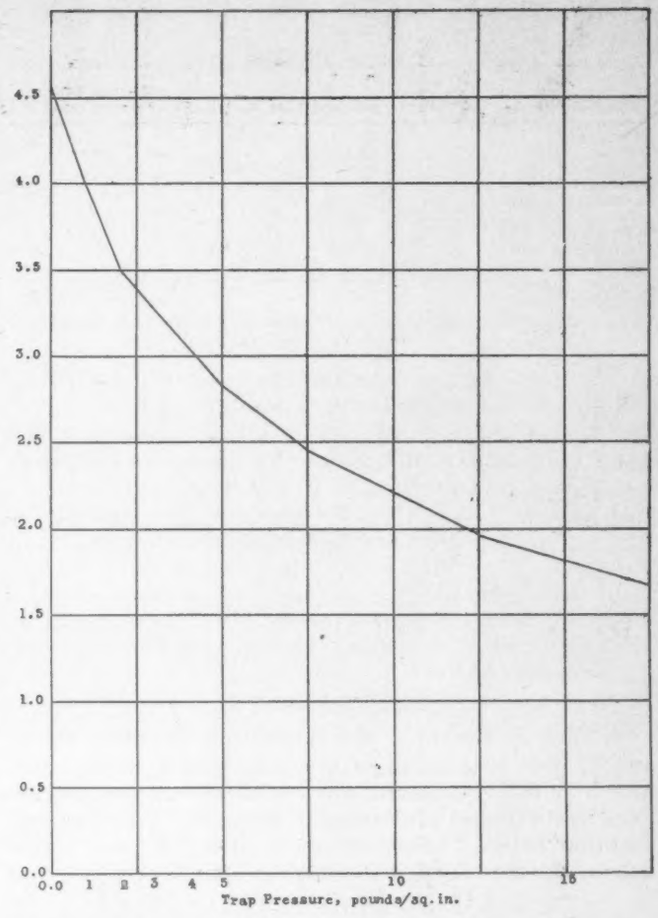
The capacity of the plants now in operation in the East Texas field is sufficient to process all of the gas produced at present, but field conditions, distances from wells, and other factors, leave room for erection of additional plants in the future. The volume of gas available for processing through the plants depends upon the allowable oil produced, and the gasoline content (26/70 and heavier) is apparently in inverse proportion to the pressure maintained upon traps and oil and gas separators. Surveys made by some of the larger manufacturers of natural show that when the oil and gas separators are adjusted to operate with a back pressure of only 20 pounds, gauge, the available gasoline that can be recovered from the gas will be in the neighborhood of 1.5 gallons per thousand cubic feet. With the trap pressure lowered constantly, the gasoline content gradually rises until the point where the trap pressure is at zero pounds, or under one atmosphere, as much as 4.5 gallons per thousand cubic feet can be extracted. This is shown in the accompanying chart.

Not all of the producers of crude oil have made field conditions ideal for extraction of the maximum available gasoline. Due to the fact that when the field was drilled intensively, a great number of the oil and gas separators were placed on the ground. The fact that a certain amount of pressure must be maintained on these traps prevents the gas from removing the heavier fractions of natural gasoline from the oil.

When other conditions prevail, such as proper elevation of the separators, the oil flows through the liquid-level instruments and float valves when a slight vacuum is placed upon the oil. No doubt, as the value of the natural gasoline, and incidentally the butanes and propane, is more generally recognized, most of the ground-level traps and separators will be moved from their present position and placed upon elevated structures so that all available natural gasoline may be removed and saved. Otherwise these valuable constituents usually weather from the oil while it is in the lease tanks and before passing into the pipe line system.

Under the present average field conditions existing in the East Texas field, the volume of gas produced from the oil is approximately 340 cubic feet per barrel of oil. The production of natural gasoline during 1935 was estimated at 89,468,640 gallons, none of which exceeded the normal grade of 26/70. Grades from 9 pounds, Reid, including 12, 14, 18 and 22 pounds, Reid, were manufactured, but no figures showing the relative quantities of such products are available.

Calculated upon the basis of the reported legitimate oil produced in the field for the year 1935—which was 172,528,526 barrels—the natural gas volume was 58,660,000,000 cubic feet. With an average yield of 2.75 gallons per thousand cubic feet processed, the total natural gasoline manufactured should have been around 161,315,000 gallons, if all the gas had been processed through the recovery plants. However, the reported total production of natural gasoline for the year was only about 55 percent of the total indicated above, and which might well have been recovered from the gas if all wells had been connected to plants, and all of the gas processed. The above figures include only that gasoline which was produced, or could have been produced, falling within the range of 26/70 grade, or lower vapor pressure.



Graph made from a survey of wells and leases with operations under different trap pressures, showing the effect of pressure on yield of natural gasoline in the East Texas field

Propane and butane production would have been in immense volume, if we base the entire field production upon the following analysis of a typical sample of East Texas gas:

COMPOUND	Volume, percent	Gas/M. Cu. Ft.	Liquid Volume Percent at 60° F.
Methane	40.56	.....	.....
Ethane	15.90	.....	.....
Propane	24.62	6.72	.....
i-Butane	3.20	1.03	.....
n-Butane	9.44	2.96	.....
i-Pentane	2.03	.74	.....
n-Pentane	2.10	.76	.....
Pentane and heavier	.....	.....	.....
Hexane and heavier	2.14	.92	.....
Total	.....	14.13	3.56—26/70

Residue from the same plant, taken over a 24-hour

period and at the same time that the foregoing wet gas sample was secured, shows the following:

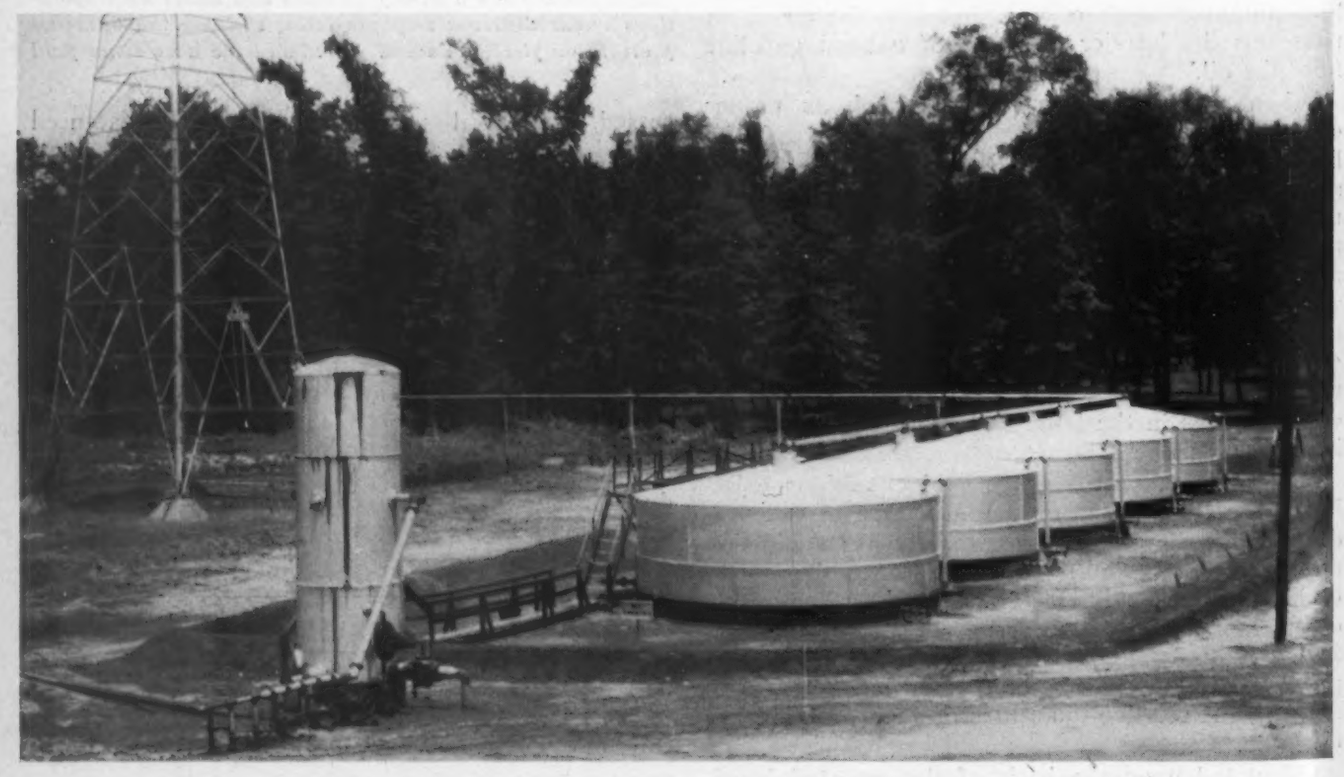
COMPOUND	Volume, percent	Gas/M. Cu. Ft.	Liquid Volume Percent at 60° F.
Methane	43.77	.....	.....
Ethane	16.45	.....	.....
Propane	25.50	6.99	.....
i-Butane	4.33	1.40	.....
n-Butane	9.82	3.08	.....
i-Pentane	.....	.....	.....
n-Pentane	.....	.....	.....
Pentane and heavier	.13	.06	.....
Hexane and heavier	.....	.....	.....
Total	.....	11.53	0.87—26/70

The total liquefied petroleum products, including 26/70 natural gasoline, which could have been manufactured from natural gas in East Texas, for the year 1935, and if the plants had been in operation for this type of extraction, would have been 828,865,800 gallons (19,735,850 barrels), or .114 percent of the reported legitimate oil produced from the field for the year. Which is an indication of what proper field management, proper cooperation and coordination, and most efficient scientific extraction processes may accomplish when such achievement is economically desirable.

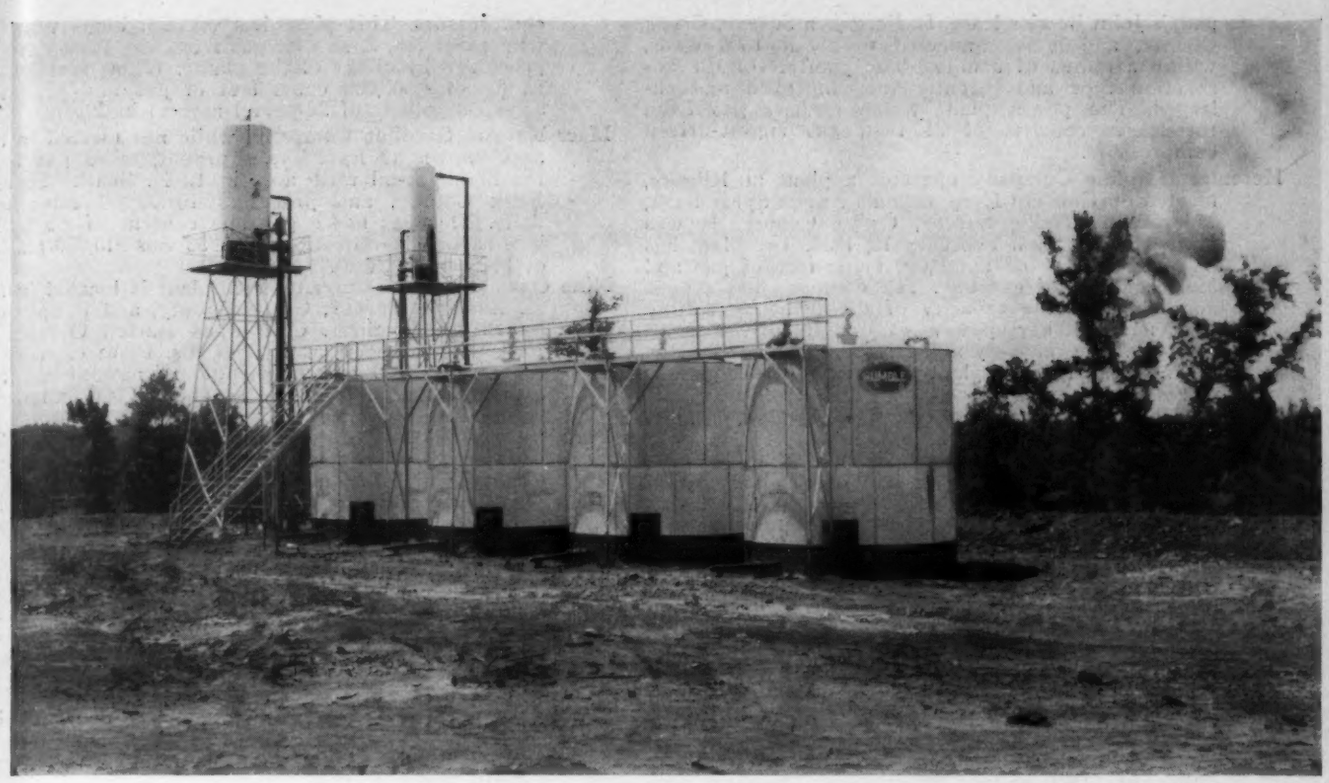
EARLY PLANTS

A few of the first plants erected in East Texas might well be termed of the "composite" type, inasmuch as the equipment was for the most part assembled from materials secured from shut-down plants in other fields. These were more or less hastily erected, with the view to securing "flush" production with as small an outlay of money and material as possible. Experience gained through the operation of these plants, along with others of the most modern type, has indicated conclusively that if natural gasoline is to be produced in this field, as in others, slip-shod operating conditions will not suffice. Therefore, the plants which have been erected within the past two years have all been of modern type and new equipment, and the older plants have been or are being revamped and modernized. Atmospheric conditions are not at all ideal for the most efficient extraction of natural gasoline because of low wind velocity and high relative humidity. These factors prevent the securing of desired temperatures on cooling water without the most efficient type of water-cooling and handling equipment.

Because of the desire on the part of many oil producers to obtain the maximum amount of crude oil that could be sold (some of it reputedly "hot oil") oil traps have in many instances been taxed above their capacity with the consequence that some of the oil is "pulled over" with the gas. Oil so accumulated in pipe line drips and in plant scrubbers is classed as "scrubber oil" and often presents a serious problem to the gasoline-plant operator. If the volume of oil accumulated in the gasoline-plant system does not exceed three-fourths of a barrel per well per month, both state and federal tenders may be secured and the oil may be sold to pipe lines. However, there is a bright side to this situation, for plants with well connections running up into the hundreds, and often above a thousand, may have an income from this source of several hundreds of dollars monthly.



Type of field tank battery setting which requires back pressure on the oil and gas separator and secures lower gas volumes and lower yields of gasoline



Separator mounting in the East Texas field arranged so that the maximum amount of gasoline is secured from the gas produced with the oil

Active Natural Gasoline Plants in East Texas

Following is a list of active gasoline plants in the East Texas field, as of July 1, 1936.

Arkansas Fuel Oil Company, formerly Harmony Gasoline Company, operates a low-pressure absorption plant near Greggton. The plant is located on Stanolind Oil & Gas Company's Smith lease, Gregg County, and has a maximum gas capacity of 8,500,000 cubic feet. The gasoline capacity is 20,000 gallons, but under present conditions 6,500,000 cubic feet of gas is being processed from about 1075 wells to produce about 17,000 gallons. Gas processed through this plant has a gasoline content of 2.60 to 3.25 GPM, sweet and non-corrosive. The plant was placed in operation April, 1932, and the reported production for 1935 was 5,110,000 gasoline, 10- and 20-pound grades.

Casingas Corporation operates a small plant near Kilgore on the Transsate-Smith lease, Carruthers Survey, Gregg County, with a rated capacity of 1,000,000 cubic feet of gas per day and natural gasoline production of 1555 gallons. The plant is conected to but 60 wells, with gas production ranging from 1.50 to 2.50 GPM, gasoline content. Production is around 900 gallons per day of 26-pound natural.

Chief Refining & Gasoline Company's plant is located in Block L, Gladewater townsite, and consists of a 4-unit plant capable of handling 2,500,000 cubic feet of gas and producing about 5000 gallons of gasoline daily. The plant began operating January 1, 1934 and is handling 1,000,000 cubic feet of gas from 96 wells, making about 5000 gallons of 26-pound natural.

Gladewater Gasoline Company's plant is located near the eastern limit of the town of Gladewater on Meridian Oil Company's Lee lease, John Crosby Survey. It is a 7-unit plant connected to 169 wells and has a rated capacity of 2,500,000 cubic feet of gas and 5,000 gallons of gasoline per day. The present volume processed through the compression-type plant, is about 2,400,000 cubic feet, of which volume about 600,000 cubic feet comes from the refinery of Texas Oil Products Company. Total production is about 6000 gallons daily.

Gilliland-General Gasoline Company recently completed a plant at Reed Switch, Rusk County, on Luling Oil & Gas Company's lease, R. Winn Survey. All equipment in this installation is new. It is operating as a gas rectification unit with rated capacity of 10,000,000 cubic feet of gas daily and with production of 30,000 gallons. The plant was put into operation March 1, 1936.

Gilliland-General Gasoline Company also has an older plant located on Empire Oil & Refining Company's Leter lease, near the Gilliland refinery on the west side of Gladewater. The plant has a capacity of 4,000,000 cubic feet of gas and 10,000 gallons of gasoline, taking gas from the refinery and about 220 well connections. The production of this plant for 1935 was reported at 1,360,000 gallons of 26-pound natural.

Gregg Tex Gasoline Corporation started operating its original plant in November 1, 1933. The plant was remodeled and enlarged during the first part of 1936 by adding more compressors and recovery equipment. The plant is located on Humble Oil & Refining Company's Hughes lease, D. Sanches Survey, Gregg County. It is connected to 1800 wells with 13,000,000 cubic feet of gas capacity. This gas averages a yield of about 3.30 GPM when making 22-pound natural.

Gulf Oil Corporation started operations at its gasoline plant in June, 1932. The plant is located on the company's Cashion lease, H. B. Dance Survey, Rusk County, and has a rated capacity of 5,000,000 cubic feet of gas and 12,500 gallons of gasoline daily. With connections to 435 wells, the plant produced 3,650,000 gallons of 9- to 22-pound natural during 1935. Part of this was ethylized and sold as motor fuel. The plant also processes about 550,000 cubic feet of gas daily from Oil Refineries, Inc., at Overton.

Hanlon Gasoline Corporation began operating its plant in June, 1934. It has a rated capacity of 15,000,000 cubic feet of gas, and gallonage capacity of 50,000. The plant is located on Humble Oil & Refining Com-

pany's John Bowles lease, D. Ferguson Survey, Gregg County, and it is connected to about 1800 wells, within a radius of 5 miles. The plant is of the absorption type and recently was improved and enlarged. The power plant which gathers gas from the leases consists of 21 twin gas engine-driven compressors.

Hercules Gasoline Company operates a plant at Kilgore, located on Gulf Oil Corporation's Angus Spear lease, Mary Van Winkle Survey, Gregg County. It was placed in operation February 15, 1934. The plant has a rated capacity of 12,000,000 cubic feet of gas and 35,000 gallons of gasoline. The company has rebuilt and added to the capacity of the plant by setting four new 250-horsepower gas engine-driven compressors. The recovery unit is of the gas rectification type. During 1935 the plant produced 4,795,000 gallons of 26-pound natural.

Humble Oil & Refining Company's New London gasoline plant is a combination absorption-compression type. It began operating in October, 1931. Plant capacity is rated at 10,000,000 cubic feet of gas daily from over 900 wells, and production is around 21,500 gallons of gasoline. The plant is located on the company's R. E. L. Silvey lease, T. J. Martin Survey, Rusk County. The New London plant is reported to have produced 5,124,000 gallons of 12-, 18- and 26-pound natural for the year 1935.

Humble Oil & Refining Company's Kilgore plant is located on the company's Laird "B" lease, I. Ruddle Survey, Rusk County, near "Pistol Hill," a few miles south of Kilgore. The plant is powered by 12 gas engine-driven compressors, and is of the combination compression-absorption type, securing gas from 500 wells with capacity of 5,000,000 cubic feet of gas daily, and 11,000 gallons of gasoline. The plant produced 2,655,000 gallons of gasoline ranging from 18 to 26 pounds Reid vapor pressure during 1935. Gasoline is transported through pipe line and until recently was moved from the company's New London plant by tank car to Baytown. Upon completion of Humble Pipe Line Company's new 8-inch pipe line, all gasoline moves to Baytown, Texas, through the new line.

Lisbon Gasoline Company started operating its 7-unit plant May 1, 1934. This plant is located on Marathon Oil Company's W. T. Grisson lease, J. F. Brown Survey, Rusk County, and has a rated capacity of 6,000,000 cubic feet of gas daily coming from 700 wells. It produced 4,385,000 gallons of 22-pound natural during 1935, which was sold to The Texas Company.

Lisbon Gasoline Company, Plant No. 1, is located on Marathon Oil Company's E. E. Moore lease, Cadena Survey, Rusk County. It began operating in August, 1931, equipped with 13 gas engine-driven compressors. This plant has vacuum loops tying in with plant No. 2, so that gas from any lease may be processed by either of the plants. It has a rated capacity of 4,000,000 cubic feet of gas and produced 3,285,000 gallons of 22-pound natural in 1935.

Marr Natural Gasoline Company, while not located in the area known as East Texas proper, takes gas from the high gas-oil ratio area in L. N. Sparks Survey, Rusk County, and processes 10,000,000 cubic feet daily. This gas has a gasoline content of .65 GPM. The reported production for 1935 was 913,000 gallons of 14-pound natural.

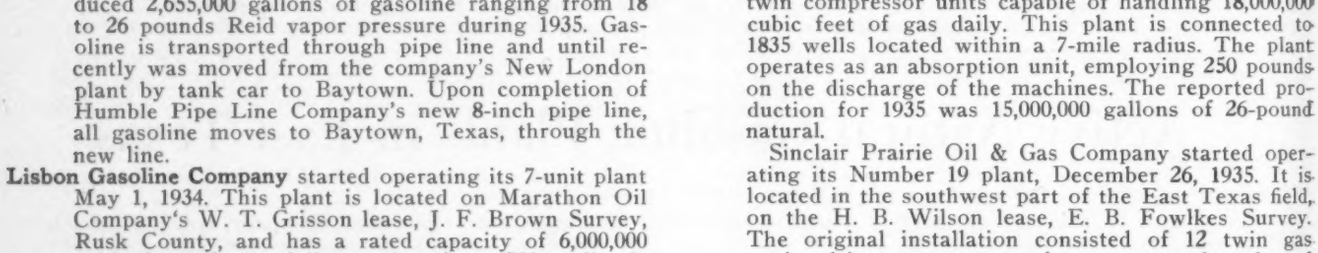
Nine Oaks Gasoline Company, Inc., plant is located in the H. Edwards Survey, Gregg County, and is operated by Prince Brothers. Operations started October 1, 1934, with connections to 25 wells. Plant capacity is reported at 3000 gallons of 26-pound natural and it is estimated that it produced around 325,000 gallons of gasoline during 1935.

Parade Gasoline Company operates a plant on Ward Oil Company's Giles lease, M. J. Prue Survey, Rusk County, which began operating in August, 1931. The plant was recently reconditioned and capacity increased to process 15,000,000 cubic feet of gas secured from 1600 wells.

Sabine Valley Gasoline Company, Inc., started operating its plant on General Crude Oil Company's L. Howard lease in the Mary Scott Survey, Gregg County, on April 22, 1935. The plant equipment is all new. Eleven twin compressors bring in gas from 1200 wells and the plant is reported to have a daily production of 30,000 gallons of 22-pound gasoline.

Sinclair Prairie Oil & Gas Company began operating its Number 18 gasoline plant on Shell Petroleum Corporation's Moore lease, J. Mosley Survey, Gregg County, April 28, 1934. The plant is equipped with 22 twin compressor units capable of handling 18,000,000 cubic feet of gas daily. This plant is connected to 1835 wells located within a 7-mile radius. The plant operates as an absorption unit, employing 250 pounds on the discharge of the machines. The reported production for 1935 was 15,000,000 gallons of 26-pound natural.

Sinclair Prairie Oil & Gas Company started operating its Number 19 plant, December 26, 1935. It is located in the southwest part of the East Texas field, on the H. B. Wilson lease, E. B. Fowlkes Survey. The original installation consisted of 12 twin gas engine-driven compressors, but was recently enlarged through the addition of 4 additional machines, which increased capacity to 13,000,000 cubic feet of gas daily. The plant produces 26-pound natural and has a rated capacity of 45,000 gallons per day. The gasoline plant is connected to 1460 wells withi na radius of 3½ miles.



Humble Oil & Refining Company's New London Gasoline Plant

East Texas Gas Gathering Systems

ELTON STERRETT

WITH an initial gas/oil ratio averaging normally only 600/1, and with the wells in the field severely restricted by proration regulation, the natural gasoline operator in the East Texas area meets many problems in securing his raw material which were not found in other, earlier fields, nor which could be forecast in the first stages of the development of the vast East Texas field.

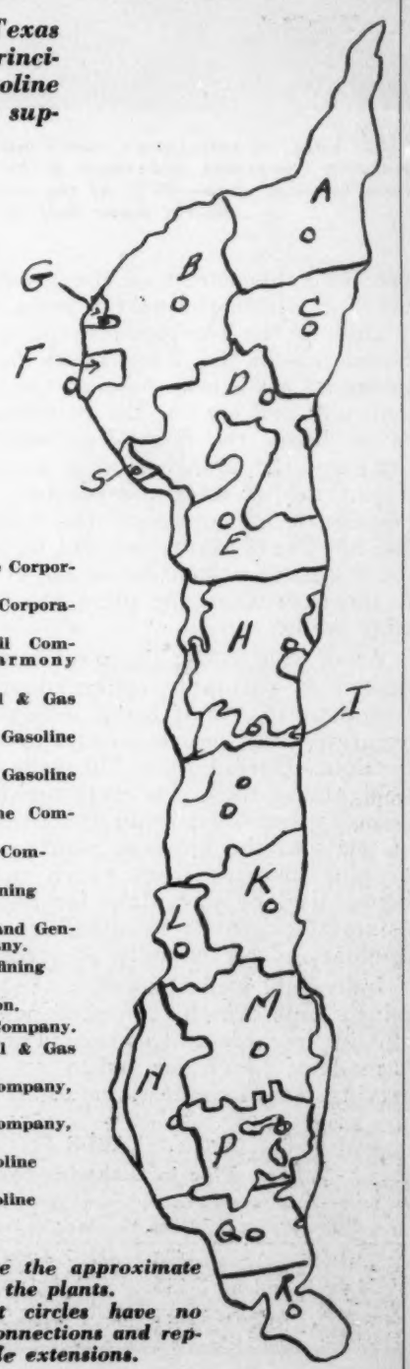
In its endeavor to hold the total output of the field to a set daily maximum of 450,000 barrels of crude, each revision of output allowable made by the Texas Railroad Commission is downward; so that by the middle of 1936 not far from 75 percent of the wells are rated at the 20-barrel minimum established by the state legislature, while the remaining 25 percent can produce but fractional amounts above this figure.

With proration restricting the output from the individual well, and at the same time maintaining the bottom-hole pressure at a figure close to that found at discovery of the field, the matter of securing its allowable from any well requires but a few minutes of flow. This intermittent flowing of wells, combined with the necessity for holding the pressure on the separator as near atmospheric pressure as possible, in order to keep the yield of gasoline as high as can be attained, make the task of scheduling and maintaining flow in the wells connected to any given gathering system one requiring tact, diplomacy and unrelenting follow-up if the gas input into the gathering system is to remain within the maximum capacity of the plant at one minute and not starve it the next.

The first-comers of the gasoline plants in the East Texas field were planned and laid out with double or treble the present gas output per well as a basis, but as the per-well output decreased the number of wells connected has increased, providing a total input into the gathering system equalling or even slightly surpassing that originally contemplated.

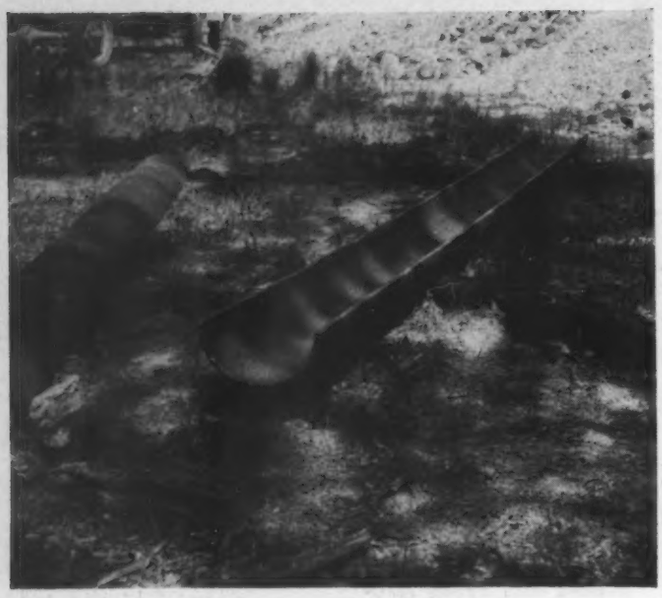
Many of the earlier gathering systems, salvaged from other and then exhausted fields, were hastily reconditioned and relaid in East Texas, with the expectation of a probable field life of from 5 to 10 years. Now that the area is well into its sixth year of production, with a probable further life assigned it of from 15 to 25 years, this salvaged pipe already is proving a source of trouble. Where plant capacity has been increased, and the initial gathering system was inadequate, much of this early line has been lifted and replaced with new pipe, but there still remain amounts of old line varying from a few miles up to 50 percent of entire gathering systems. Estimates by various authorities sched-

Outline of East Texas field showing principal natural gasoline plants and areas supplying gas



A—Gregg-Tex Gasoline Corporation.
B—Hanlon Gasoline Corporation.
C—Arkansas Fuel Oil Company (formerly Harmony Gasoline Company.
D—Sinclair-Prairie Oil & Gas Company, No. 18.
E—Sabine Valley Gasoline Company, Inc.
F—Gilliland - General Gasoline Company.
G—Nine Oaks Gasoline Company.
H—Hercules Gasoline Company.
I—Humble Oil & Refining Company.
J—Crescent and Gilliland General Gasoline Company.
K—Humble Oil & Refining Company.
L—Gulf Oil Corporation.
M—Parade Gasoline Company.
N—Sinclair Prairie Oil & Gas Company, No. 19
P—Lisbon Gasoline Company, No. 1
Q—Lisbon Gasoline Company, No. 2
R—Marr Natural Gasoline Company
S—Gregg County Gasoline Company.

The circles indicate the approximate location of the plants. The areas without circles have no gathering system connections and represent possible extensions.



"Half soles" of split casing coated internally with corrosion-resisting compound and ready to be welded to gathering lines at weak spots—90% of the corrosion damage being on the lower half of line

ule the replacement of the greater portion of this old line within the next 5 years.

Due to the elongated shape and interlocking of leaseholds in the East Texas field, in only a few instances has it been possible to choose the plant site centrally and lay out the gathering system on what is in theory the most economical scheme—that of doubling the branches in symmetrical "tree" form as the farther wells are reached. In the others the plant was, for topographical reasons, placed nearer the flank of the area covered by the system, calling for a greater proportion of larger sizes of pipe than is the case when the plant is equidistant from the edge wells.

As of July, 1936, the total number of wells connected to natural gasoline plants totalled slightly less than 15,000—it being impossible to present an accurate, fixed figure because of daily shifts in connections. During June, 210 wells were added to the field, and of these, 146 were tied-in to existing gathering systems. To bring gas from the vast number of wells to the gasoline plants required 715[1] miles of pipe in sizes from 4-inch to 24-inch, this last being used by one plant for headers and to serve as storage capacity to absorb or dampen out severe fluctuations occasionally occurring in line pressure.

Individual well connections require an amount of 2-inch pipe which, compiled where possible from existing records and estimated where no separation is made of 2-inch devoted to gas gathering and that serving for oil connections, totals approximately 500 miles; or, on a weight basis, this one item of small line amounts to around 4900 tons.

TABLE I

Pipe in Gathering Systems

Size	Miles	Weight, Tons	Value
2-Inch	500	4,900	
4-Inch and up	715	29,500	
Total	1215	34,400	$3,500,000

[1] Approximate only, as many material sheets do not include recent changes in extent or size of pipe used.

On the gathering lines represented in Table I are approximately 1500 meters of various types and capacities, each connected in series with a regulator to maintain the desired separator pressure.

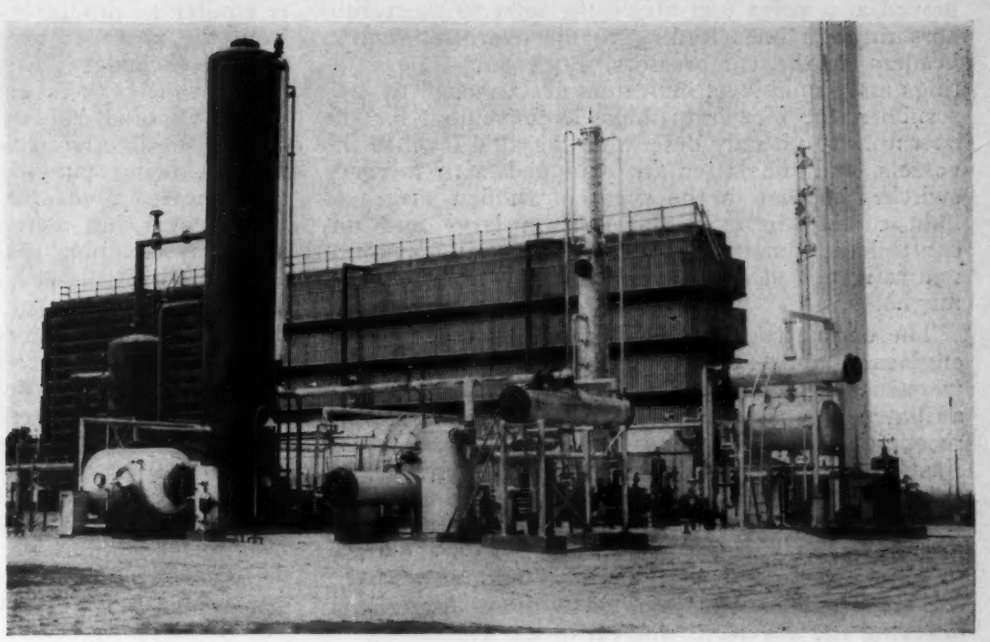
In addition to requiring the covering of most of the field with its network of gathering line pipe, the work of bringing the gas to the natural gasoline plants requires the services of line gangs, meter readers or "chart snatchers" and others employed between the separators and the compressor headers ranging on various systems from 10 to as high as 40 men—with a field total of around 300. Augmenting the men regularly employed on the gathering systems are temporary forces of twice that number utilized in the work of replacing or reconditioning present lines, making emergency extensions, and in other maintenance.

Those gathering lines connected to wells which are making little or no water present corrosion problems on the outer surface only, and any replacement on them is due to the presence of "hot spots" in the terrain traversed by the line. Those lines serving wells which are making salt water with their oil, however, more than double the trouble from corrosion, as the internal wasting away of metal is certain and rapid, being most severe in the low places in the line in the immediate vicinity of the drips placed there to remove entrained oil and condensation.

With this problem of dual corrosion to meet, several of the score of natural gasoline plants have begun extensive programs of line replacement or reconditioning as protection against failure. In one instance some of the worst low spots have been "half-soled"—the original line being uncovered and its lower half reinforced by arc-welding sections from pipe or casing which, when split longitudinally, will fit closely around the gathering lines. As an example, 8-inch lines are being reinforced by having split 9⅝-inch casing welded along the lower half. These low spot "half-soles" extend from one joint up to as high as 20, depending upon the gradient of the gathering line and the presence or absence of severe external corrosion at the same place. This system of line reinforcement enables the work to be done without cutting the line, or in any way interfering with its normal use as gas carrier.

Present corrosion studies in the field indicate that those gathering lines which are uniformly active—i. e., carrying gas in motion as contrasted with stagnant gas—throughout most or all of each 24 hours are much less susceptible (other conditions being equal) to corrosion troubles than are those where the daily flow through the line is of but short duration. In one instance where earlier flow schedules left one line inactive the greater portion of each day, re-scheduling the wells to maintain practically regular gas flow soon eliminated the tell-tale rusty taint in the run-off from the low-spot bleeders.

Although handling what is regarded as only a by-product in crude oil production, the gathering systems of the East Texas field practically equal in tonnage of pipe used the systems handling the crude itself, and although measuring little more than half the length of the oil carriers, represent an investment within half a million dollars of that put into oil lines.



Distillation and final stabilizer at Hanlon Gasoline Corporation of Texas, East Texas gasoline plant

Hanlon Absorption Plant

HANLON GASOLINE CORPORATION of Texas operates one of the few straight oil-absorption plants in East Texas. This company's plant is located on Humble Oil & Refining Company's John Bowles lease, D. Ferguson Survey, Gregg County, 5 miles northeast of Gladewater. Until about the middle of 1935 it was classed as a 14-unit plant, but increased recently to 21 units. A unit in an East Texas gasoline plant means an engine-driven compressor, so all plants are rated as so many units capacity.

Being the key plant in East Texas for a gathering system which picks up gasoline from many of the other companies in the field for Hanlon-Buchanan, Inc., the marketing organization for Hanlon Gasoline Company of Texas, and others in this area, perhaps more attention is given to producing conditions than at any other plant in this section. A close co-ordination is maintained at all times with the producing companies in order that wells may be produced on an equitable basis with respect to gas delivery to the plant.

The plant takes gas from approximately 175 leases, the majority of which are operated by major producing companies, and covers an area of approximately 5 miles radius. More than 100 miles of field lines were laid to serve this large area, some of which are 20 inches in diameter. Eight main-line gathering systems converge at the plant, all coming in under uniform master meter settings so that a double check may be secured of the gas coming from the various leases in the field. The system is protected by numerous field drips located at the points where most line accumulation is found, and equipped so that the oil may be drained from the drips and trucked to the plant scrubber-oil storage.

Four scrubbers were installed in the plant yard. These are located so that the 8 main lines entering the plant can be connected by twos to each scrubber tank. Each line as it rises from the ground makes two 45° turns, one in breaking from the straight line of the main, and the other when it again assumes a horizontal position to form the meter run. The sections of pipe which form the meter setting are supported in a permanently horizontal position by concrete cradles to prevent distortion. The customary orifice meter flanges are used in these meter settings with individual orifice meter recording units installed.

The scrubbers are vertical vessels similar to field oil and gas separators, having the gas inlet considerably above the center section. Baffles attached to the inside of these vessels deflect the gas and fluids to the base where they are separated. Gas is re-

moved at a point just above the inlet to the scrubbers through lines leading to the overhead suction headers at the compressors. Both gauge-glass fittings and liquid-level indicators are attached to each scrubber, the former to make it convenient for the operators to visually determine the fluid level in the vessels, and the latter are equipped with mercury switches so that in the event of sudden surges of fluid coming in from the field in large and uncontrollable quantities, the engines will be automatically placed out of service by shorting out the magnetos.

The engine room, including various types of gas engines, totals 2995 horsepower. Most of the engines were moved from other plants operated by this and affiliated companies. All of the used engines were reconditioned before being placed in service in the East Texas plant. The engine room is operated as a single-stage compression unit, taking suction on the intake headers at about 10 inches, mercury, in order that sufficient vacuum may be placed on the traps to obtain the greatest amount of natural gasoline fractions from the gas and oil without appreciably lowering the gravity of the oil in the separators.

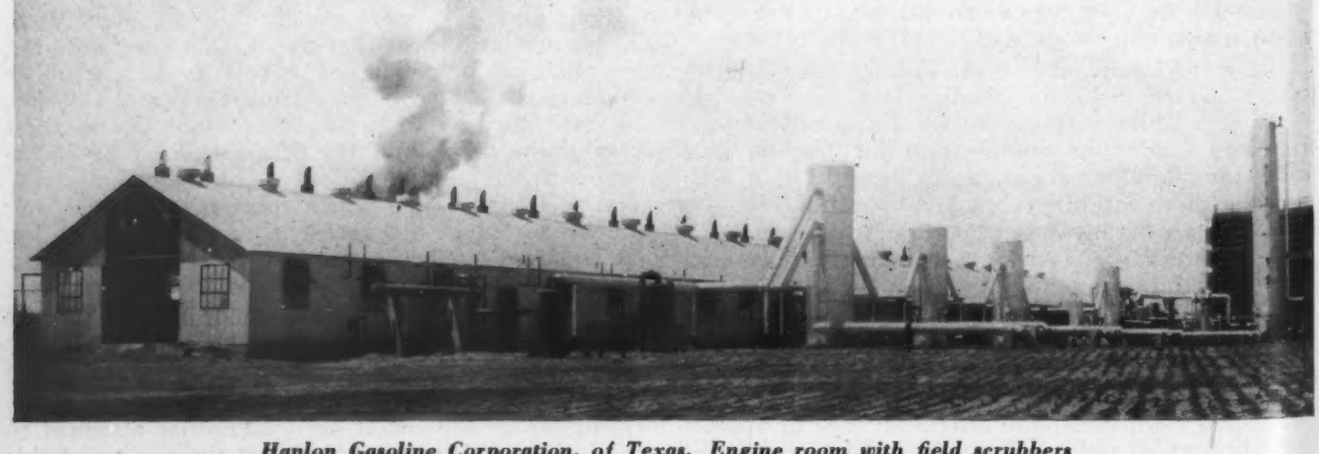
The discharge pressure maintained upon these compressors is held at 50 pounds, in order that efficient extraction may be secured without excessive mineral seal oil circulation. Cooling of the gas is secured by passing it through conventional atmospheric sections placed in a water-cooling tower, traveling through scrubbers, or condensate accumulators, before entering the absorber. This column is 6 feet in diameter, equipped with 2 intercoolers through which the oil passes while traveling downward toward the outlet in the base of the tower. Prior to entering the top of the column the oil is passed through an additional cooler to lower the temperature from that obtained by passing it through the atmospheric sections. This cooler is a shell-and-tube unit with gasoline stabilizer overhead condensate expanded in the shell to obtain the desired refrigeration. The capacity of the absorption section of the plant recently was increased by the addition of the second column so that more of the lower boiling fractions could be extracted from the gas, in order that they may be shipped by pipe line to the Gulf Coast for polymerization at Humble Oil & Refining Company's Baytown refinery.

The operation of the distillation unit in this plant is similar to others of this type, with the rich oil from the absorber being pumped through a series of heat exchangers to a rich-oil vent tank. The oil in the vent tank is under process pressure at this point. Vapors removed from the oil at exchanger heat pass directly to the still through a vapor line without being pumped with the oil through the steam-heated preheater. This arrangement not only saves steam, but increases the capacity of the preheater by confining it to oil heating alone.

Stripping of the rich oil is secured in the vertical still with the denuded oil flowing in a cycle back through the exchangers and to the absorbers. Vapors, refluxed to the desired end point, are removed from the usual overhead vapor line and are condensed in a tubular unit from which the liquid flows to a surge tank. Pumps pick up this raw material from the tank and discharge it through conventional exchangers to the final fractionating column, a tower containing 36 plates. By adjusting the pressure on the column, the temperature in the reboiler, the temperature of the feed and the temperature at the top of th tower, gasoline of any desired vapor pressure may be obtained as a bottom product. It is said that a 26/70 natural gasoline may be manufactured in this column that contains nothing in its composition excepting normal butane and heavier. The minimum vapor pressure base product that can be removed from the column is a 14-pound natural gasoline. Higher vapor pressure than the usual 26/70 is manufactured when demanded containing propane in such proportions as may be desired by the buyer.

Vapors driven from the rich absorption oil by the heat in the exchangers and released in the raw-gasoline surge tank, after passing through the still, are picked up by a recompressor and discharged directly to the final fractionator where the desired hydrocarbons are recovered by vapor rectification. These vapors are discharged directly to the column at the normal heat of compression without being directed through condensers or coolers.

The usual type of oil-country boilers are used in this plant. They are located at a distance from the plant proper. Condensate from the pre-heaters and exhaust steam is returned to the boiler plant to be reconverted to steam. Two vertical pressure vessels are used as boiler makeup water supply tanks with sufficient pressure held upon them to prevent escape of water vapors.



Hanlon Gasoline Corporation, of Texas. Engine room with field scrubbers and master meter runs. Absorber at left.

Safe Methods *Featured At* Gregg-Tex Plant

GREGG-TEX GASOLINE CORPORATION began operation of its gasoline plant, located on Humble Oil & Refining Company Hughes lease, D. Sanches Survey, Gregg County, Texas, on November 1, 1933. When the plant was placed on production it was considered a small unit, using only 5 400-horsepower gas engine-driven compressors. As drilling became more concentrated, naturally larger volumes of gas were made available for processing. The company recently expanded the plant to a point where it can handle about 15,000,000 cubic feet of gas daily.

At the time of installing additional gas engine-driven compressors, the recovery side of the plant also was enlarged and a new final or liquid fractionator was placed in operation. To care for the added gas, 2 400-horsepower gas engines were installed, together with 5 250-horsepower units of modern type. The plant as it is now operated consists of 2 duplicate units, having 2 gas fractionating columns to which the entire engine room delivers raw gas, with the volume controlled so that each column receives an equal amount of raw material for processing. Additional water-cooling facilities were required because of the larger amount of heat to be extracted, so the existing louvre towers were enlarged. The cooling unit used to reduce the temperature of engine jacket water was increased in capacity from 900 gallons per minute to 1800 gallons per minute. Another louvre tower, used to cool the gas and gasoline cooling water was increased from a capacity of 1200 gallons per minute to 2700 gallons per minute. This made it necessary to add more water circulating pumps.

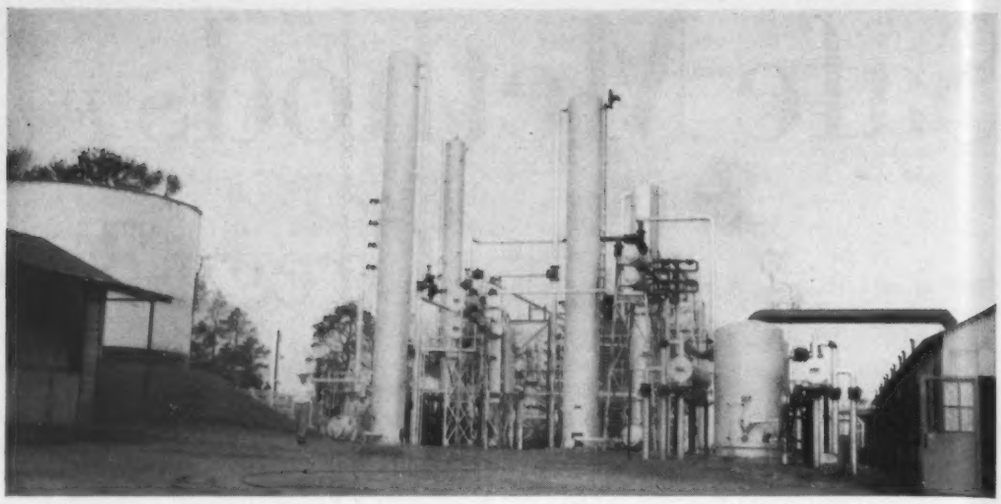
With connections to 1800 flowing wells within a radius of about 5 miles from the plant, it is necessary to use extreme caution in removing gas from the lease oil-and-gas separators and transmitting it from leases through the gathering lines to intake headers at the plant. Because of the method used in East Texas when flowing wells to allowable production of oil per well per day, a varying amount of oil is carried by entrainment with gas from the separator outlet to the gathering system. Field-line drips were installed at advantageous points in the gathering systems to remove the fluid before it enters the main vacuum lines.

Due to the precautions taken by both producers of oil and the company, a very small amount of pipe line oil reaches the header scrubber at the plant. Fluid in natural gasoline plant vacuum lines in East Texas is classed as "scrubber oil," to which no producer will claim title, if it is pipe line oil, but natural-gasoline operators have been given authority to dispose of a certian amount by federal and state tenders. The amount of "free oil" being picked up and saved through gasoline plant scrubbers recently was established as three quarters of a barrel for each well connected during any month. Volumes in excess of that amount may not be sold or transferred, and the only recourse left to the gasoline plant operator is to burn it in pits near the plant, or along the right of way as it is removed from the pipe line drips.

The usual scrubbers were installed at the plant where the field lines join with the compressor suction headers. Vertical vessels were installed to prevent the fluid from entering the compressor cylinders. At times slugs of oil and other fluids enter the header scrubbers above what amount the field line drips can handle, and in order to prevent cylinder breakage, automatic instruments were installed on liquid level apparatus to which electrical devices were attached to shut down the engines when a large volume of fluid enters from the field. Mercury switches were installed in multiple, so that in the event of a failure on one controller, the second will be sure to function. It is mandatory upon the operating personnel of this company to see that the wiring is on the instruments attached to the scrubbers and the magnetos at all times and it must be in working condition.

Two systems of gas lines were laid to bring the gas into the plant from the field; one of which is called the west gas system, and the other the east gas system. Both are connected to the suction header, but at opposite ends. The volume delivered through the west gas system is considerably the larger, but at the same time has a slightly lower gasoline content, and is subject to surges of gas when a large number of wells are flowed. To prevent these surges from overloading the compressors, an automatic valve was placed on the header at the point where the gathering header is attached to the suction line of the engines. This valve gradually closes the west side gathering system from the plant as the pressure builds up. This valve was made from a large rising-stem gate valve, and is operated through a piston and cylinder actuated by pressure from an automatic controller placed on the body of the gate.

After the gas has been cleaned and the oil and other fluid scrubbed from it, it is taken into the cylinders of the compressors at an average of 10 inches of vacuum, mercury measurement, to be compressed through the first stage to about 45 to 50



Gas fractionation and stabilization equipment in Gregg-Tex Gasoline Company plant in East Texas. Columns on right are gas fractionation equipment and column in left foreground is final stabilizer

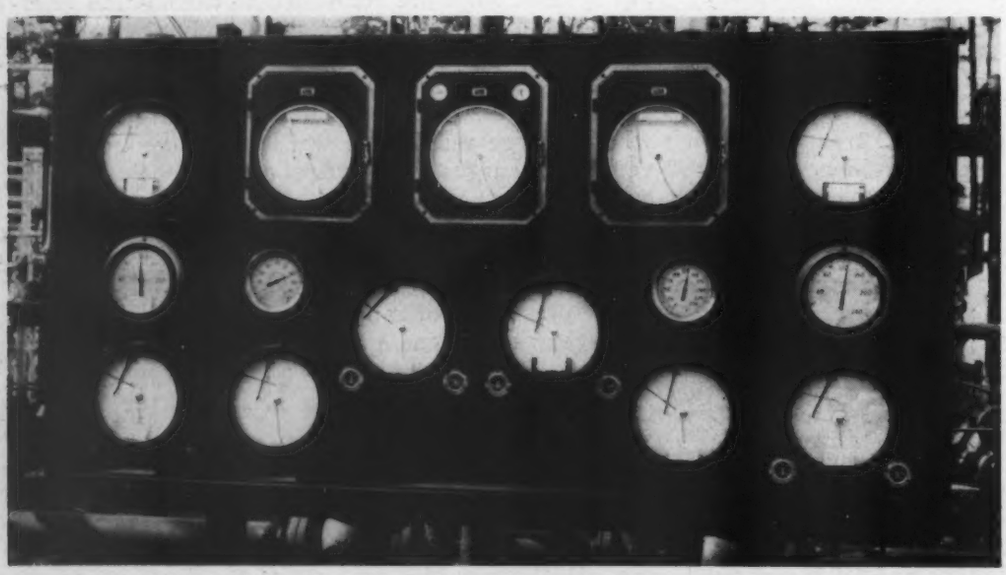
pounds. First-stage coolers were installed, using enclosed tube and shell equipment placed upon supports beside the low-stage accumulator, or scrubber, where water and liquefied gases are trapped from the gas as it is condensed in the intercooler sections.

The gas engine-driven compressors are equipped with 20-inch stroke cylinders, and varying in diameter with the horsepower of the machines. The new 250-horsepower engines are equipped with gas cylinders having an inside bore of 22 inches, while the 440- and the 400-horsepower engines are equipped with low-pressure cylinders 26 inches inside diameter. The inter-cooled gas is taken directly from the inter-cooler accumulator vessels by the high-pressure cylinders, where the pressure is increased to 260 pounds. The high-pressure cylinders on all machines have an inside diameter of 10 inches.

When the first unit was constructed several years ago, the gas entered the gas rectifying column directly from the discharge of the high-pressure cylinders, but when the second unit was built, pre-coolers were installed and the gas is reduced in temperature from about 235°F. to approximately 120°F. Both the gas rectifying columns are 48 inches in diameter by 45 feet in height and contain 24 trays each. The pre-cooler sections are shell and tube units attached to the columns by adequate piping and resting on a steel tower built between the low-pressure inter-coolers and the gas fractionating columns. These sections are 20 inches in diameter by 10 feet in length, water being used to reduce the temperature of the gas before it is introduced into the rectifying columns.

The volume of gas processed through both units of this plant varies from day to day, and from hour to hour, but an average of about 13,000,000 cubic feet are handled each day. The two divisions of the field produce a different quality of gas, as to gasoline content. The east system gas is slightly richer but the difference is so slight that no separation is made in the plant and both commingle through the compressor cylinders and are processed in both columns simultaneously.

The top temperature of the rectifying columns is maintained at about 120°F. by refluxing them with condensate recovered from the overhead stream. Reflux condensers, 2 in number on each column, 30 inches in diameter by 8 feet in length, are adequate to condense sufficient liquids for this purpose. A reflux accumulator tank on each column (4 feet by 8 feet), serves as a working vessel, but to be sure that sufficient liquids are available at all times, a



Plant control board Gregg-Tex Gasoline Company

surplus tank was installed (5 feet in diameter by 20 feet in length), to store the material so that the plant may be started again without loss of production. This tank is maintained full at all times. There have been a few times in the operating life of the plant that the safety devices on the intake scrubbers operated because of a slug of fluid being received from the field, and when they had been cleared of the crude, sufficient reflux was on hand in the surplus reflux tank to permit resumption of operation without loss of production.

Low-pressure gasoline, made in the inter-coolers between the low-pressure and the high-pressure cylinders, is slightly off color at times, due to contamination by a small amount of fine particles of crude in the gas. This material is passed through bleaching apparatus to remove the color, using clay for the purpose, and pumped to the rectifying columns with the gas, or processed in the gasoline stabilizer with the normal production.

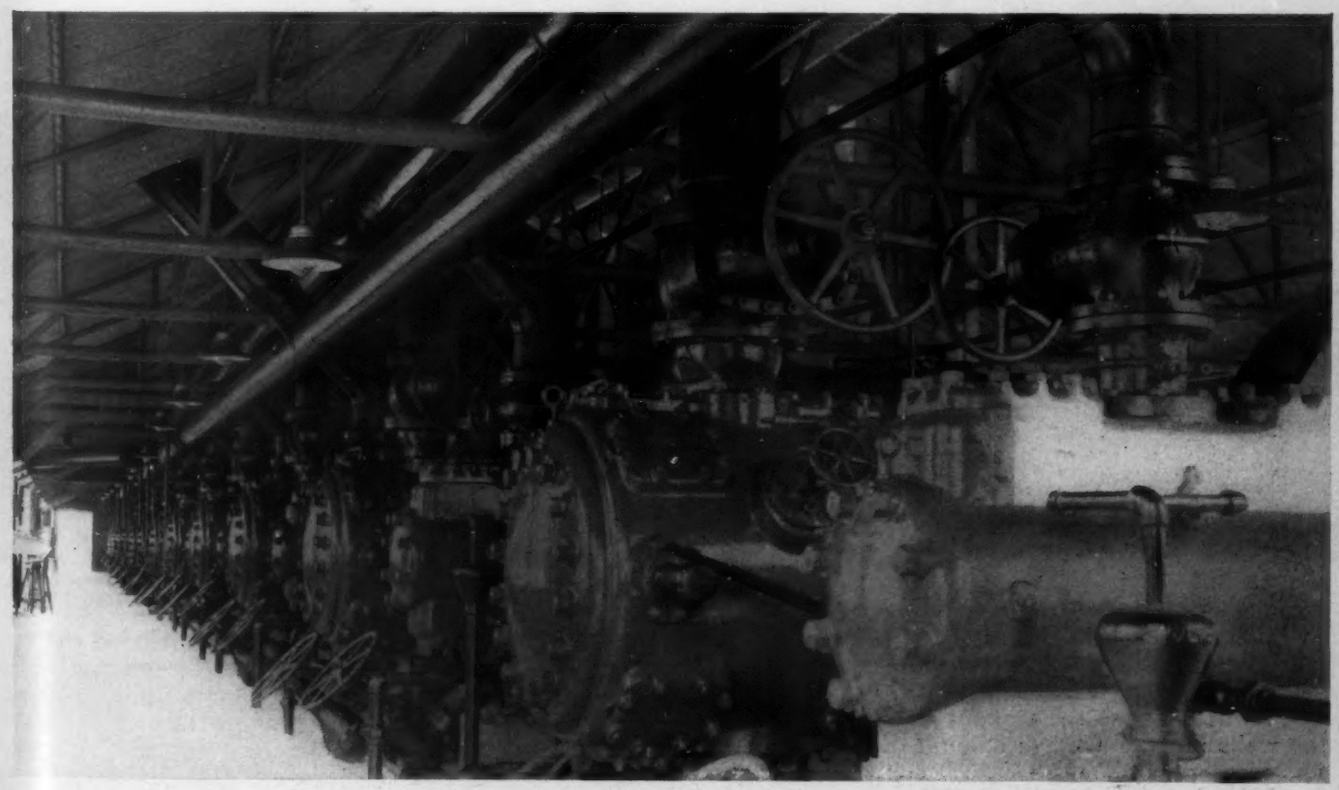
At the time the recent improvements were made a new final stabilizer was installed. The new column is 42 inches in diameter and 54 feet in height, containing 30 trays for efficient fractionation, or stabilization of the liquids. The gasoline made in the 2 gas-fractionation columns is vented to a working tank with a capacity of 24,000 gallons. From this tank it is removed by a 10x6x12-inch simplex, close-clearance steam pump and delivered to the final fractionator, or stabilizer. Overhead condensate is obtained by passing the vapors from the top of the stabilizer through a reflux condenser (2 feet in diameter by 6 feet in length) and collected in an accumulator vessel and returned to the stabilizer as an overhead trim by an 8x7x18-inch reflux pump. The temperature of the overhead stream varies as to the vapor pressure of the product desired, as well as the temperature of the reboiler, or kettle, on the base of the stabilizer. The pressure on the column is held around 200 pounds, varying only the temperature to obtain products varying from 14-pound to 26-pound, Reid, as finished natural gasoline.

The following tabulation will give some idea of the conditions in the plant when manufacturing different grades of natural:

No. 1		No. 2		No. 3		No. 4		No. 5	
Percent Over	° F.	Percent Over	° F.	Percent Over	° F.	Percent Over	° F.	Percent Over	° F.
IBP	56	....	62	....	72	....	78	....	84
5	62	....	65	....	78	....	86	....	94
10	64	....	68	....	81	....	90	....	98
20	69	....	72	....	86	....	94	....	102
30	74	....	78	....	92	....	100	....	106
40	80	....	84	....	99	....	105	....	110
50	90	....	94	....	107	....	110	....	115
60	103	....	104	....	116	....	119	....	123
70	122	....	120	....	129	....	130	....	134
80	152	....	140	....	151	....	152	....	154
90	224	....	182	....	186	....	188	....	190
92	286	96.2	280	97.0	284	98.0	288	98.4	296
84.6	140	83.9	140	78.6	140	77.6	140	75.2	140
96.0	212	98.8	212	96.6	212	94.7	212	94.2	212
API		API		API		API		API	
92.7°	...	90.0°	...	87.6°	...	85.5°	...	84.0°	...

No. 1.—Raw gasoline directly from sample cocks on stabilizer feed tank, made under 260 pounds pressure, having 30.8 pounds Reid, vapor pressure.
No. 2.—Stabilized to 26 pounds, Reid, by passing through stabilizer under 200 pounds pressure, top at 180° F., reboiler at 270° F.
No. 3.—Stabilized to 22-pound product with stabilizer reboiler set at 272° F. and stabilizer top at 185° F. Pressure at 200 pounds product showing 22.2 pounds, Reid, vapor pressure.
No. 4.—An 18 pound material passed through stabilizer with reboiler at 288° F., overhead at 194° F., pressure at 200 pounds.
No. 5.—Raw gasoline reduced to 14 pound, Reid, vapor pressure with reboiler at 292° F., stabilizer top at 200° F., and pressure at 200 pounds.

The product is sweet and requires no treating either for doctor test or corrosion. Gasoline is shipped through a 4-inch loading line to Gladewater for shipment in tank cars.



Engine room interior, Gregg-Tex Gasoline Company, located north of Longview in East Texas

Design and Operating Features *of Sabine Valley Plant* Described

SABINE VALLEY GASOLINE COMPANY began operating its gasoline plant on the Mary Scott Survey, Gregg County, Texas, in April, 1935, with approximately 100 miles of gathering lines, ranging from 2- to 20-inch pipe, covering a radius of about 6 miles. The plant is connected to about 1300 wells, and uses 11 twin gas engine-driven compressors to apply a vacuum on the traps and separators at the leases. The plant was started as a 10-unit plant, and since starting operation has been down only once; then to install the eleventh compressor.

The recovery portion of the plant is what is popularly called a gas rectification system, using no absorption oil nor still. The gas is taken from the various leases under as high vacuum as is practical to apply upon the traps and separators. Production varies according to the amount of oil produced from the wells but the average amount of gas handled by this plant runs about 10,500,000 cubic feet. On June 9, 1936, the amount of gas taken into the plant through the compressors was 10,402,000 cubic feet, with 8,985,000 cubic feet metered out as residue gas. The average plant production is around 4 gallons per 1000 cubic feet of gas, which gave a production of 40,000 gallons for that day. The plant gauges, to be exact, was 40,943 gallons, which showed that the gas shrinkage due to processing was approximately 34.6 cubic feet per gallon of gasoline manufactured, which was 22-pound, Reid, when the reading was taken.

Method of installing intake and discharge headers at engine room of Sabine Valley Gasoline Company

The quantity of natural gasoline manufactured by a plant in East Texas depends largely upon the pressure maintained upon the oil production system at the time the gas is removed from the oil and gas separators. Sabine Valley Gasoline Company made provisions when laying its gathering system to reach out with as much vacuum as is physically, as well as economically possible. Larger lines than usually encountered in other fields were laid to the individual lease separating stations so that large volumes of gas could be handled under low pressures. The system of pipe lines laid throughout the area which furnishes gas for this plant was installed at a cost of approximately $275,000. The plant itself, within the yard, cost about $270,000, a total of around $545,000.

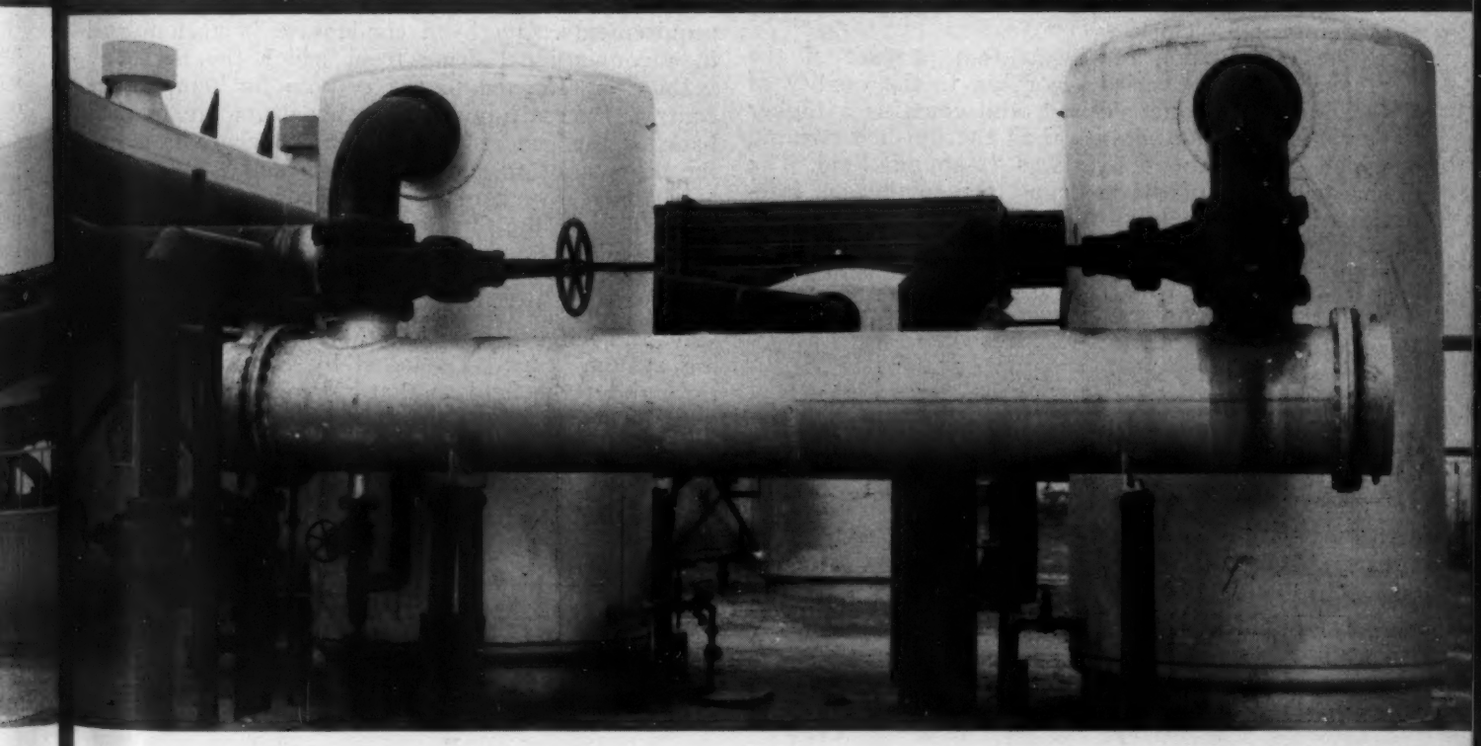
With an average production of 40,000 gallons of gasoline per day, and with a price, say, 3 cents, the time necessary to retire the cost of the plant, not counting maintenance or wages, would be about 20 months. So the company worked on the premise that with an investment of such size, it would not be wise to install anything but new equipment. With an operating period of 14 months and having only one shutdown, and that voluntary, new equipment has proven to be the most economical.

Naturally, with a gathering system as extensive as that necessary for any plant in East Texas, a large number of field meters are required to measure the gas coming from the wells. Sabine Valley Gasoline Company has constructed 100 meter loops in the field, and in addition to the 100 orifice meters installed on these measuring stations, additional meters were installed in the plant yard as master meters, and to measure the gas from the gas rectifying column, as residue. Master meters installed on the main gathering lines entering the yard from different sections of the surrounding productive area are not mounted upon standard elevated meter settings, but are attached to orifice flanges built into the line when it was laid in the ditch.

Fluid is prevented from entering the plant system to any great extent by the use of numerous drips placed at points on the various leases where oil is likely to accumulate in quantities sufficient to create an obstruction in the vacuum lines. By paying particular attention to these drips and keeping them free from oil by dumping them regularly, very little oil actually reaches the scrubbers at the engine room. The meters on the lines entering the plant are therefore, free from "fluid charts," and are easily computed.

Gas measured by the master meters enters the engine room through 2 scrubbers placed against the wall of the building, leaving room enough for passage between them and the building. With a vacuum of an average of about 10 inches, mercury, the gas passes from these scrubbers to a horizontal header placed on steel supports outside the building. Individual suction lines lead from this large header to the compressor cylinders of the 11 engines. Two-stage compression is used in this plant, the first from a vacuum to about 40 pounds is obtained through cylinders 21 by 20 inches.

Gas from the low-pressure cylinders is discharged through inter-coolers outside the building, and beside the inter-cooler accumulator tank. The coolers



Section of dual interstage gas coolers in Sabine Valley gasoline plant

are tubular enclosed water serviced units, placed on low supports for convenience in cleaning. In order that all oil coming from the compressor cylinders may be trapped out before it enters the coolers, a preliminary scrubber was set for the gas to pass through before it enters the enclosed cooling sections. The high-stage compressor cylinders take suction on the header attached to the last scrubber on the inter-cooler sections, compressing the gas to the pressure desired for adequate stripping of the gas in the gas rectification column. The superintendent stated that no pressure drop existed between the low-pressure discharge and the high-pressure intake.

The gas from the inter-coolers is taken directly to the intake of the high-pressure cylinders, 10x20 inches, and delivered to the recovery unit. The pressure used in this unit on June 5, was about 200 pounds, after the gas had been cooled from the heat of the second stage of compression, to 130°F. A high-pressure scrubber is placed beside the recovery column through which all the gas passes before it enters the pre-coolers. After passing through the 24 stripping and fractionating trays in the recovery column, the residue with the lighter fractions is directed through 2 shell-and-tube condensers, where sufficient liquids are produced to control the top section of the recovery column. The temperature of the feed to the reflux section of the recovery column was averaging around 93°F. The temperature varied from 90°F. at 8 o'clock on that morning to the highest temperature recorded, 99°F. at 2 p.m., fluctuating throughout the day to a low of 85°F. the following morning at 8 o'clock.

The composition of the bottom product of the recovery column varies according to the quality of the finished product desired, and contains a higher percentage of the butanes than the finished natural, which on the above date was 22-pound, Reid. The characteristics of the field gas feed to the gas fractionation column is as follows:

COMPOUND	Mol. Percent	G. P. M.
Methane	39.10	.....
Ethane	13.60	.....
Propane	28.65	7.82
i-Butane	2.70	0.876
n-Butane	9.60	3.01
i-Pentane	2.10	0.76
n-Pentane	2.25	0.82
Hexane and Heavier	2.00	0.86
	100.00	14.146

The residue gas contains the following:

COMPOUND	Mol. Percent	G. P. M.
Methane	48.45	.....
Ethane	16.60	.....
Propane	27.60	7.541
i-Butane	2.08	0.676
n-Butane	5.27	1.650
Pentanes and heavier	.....	.....
	100.00	9.867

Most of the residue gas from the plant is returned to the field for requirements of the various leases, and the remainder as in other plants, is burned in a flare. If and when a demand is established for a higher vapor-pressure gasoline, containing practically all of the available butanes, the operation of the plant will be changed to include those fractions in the bottom product from the final column, as well as from the primary, or vapor-recovery column.

Plant temperatures as of September 5, 1935, were as follows:

Tower Water		Atmosphere		Low Compression	
In	96.6° F.	Wet bulb	76.4° F.	To coolers	111.5° F.
Out	79.1° F.	Dry bulb	79.3° F.	Out coolers	98.0° F.

Plant Temperatures as of June 6th, 1936:

Tower Water		Atmosphere		Low Compression	
In	107.2° F.	Wet bulb	76° F.	To coolers	105.5° F.
Out	76.2° F.	Dry bulb	79° F.	Out coolers	94.0° F.

On this date the plant processed 9,418,000 cubic feet of wet gas, manufacturing 33,230 gallons, with a residue volume of 8,217,000 cubic feet. The plant production was calculated to be 3.53 gallons per thousand cubic feet of gas processed, manufacturing 22-pound, Reid, gasoline. On June 5, the plant processed 10,402,000 cubic feet of gas, making 40,943 gallons, with a residue volume of 8,985,000 cubic feet. Plant production was on the basis of 22-pound gasoline, and had increased the yield to 3.94 gallons per thousand cubic feet of gas processed.

Gasoline made in the high-pressure rectifying column is trapped directly to a horizontal receiver, called the stabilizer surge tank, where the condensate from the low pressure gas coolers also is trapped. This material is constantly pumped to the final liquid fractionator to be stabilized to market requirements. Overhead condensate is accumulated in a conventional drum from which the necessary volume is returned to the column for temperature control. Excess liquids from this drum are pumped back to the gas rectifying column where it serves the purpose of an additional wash and is refractionated for recovery of whatever gasoline may have escaped from the final column, or stabilizer.

Two outlets are available for the disposition of the finished gasoline made by this company, one to a loading rack at Kinloe, midway between Longview and Kilgore, and the other through the gathering system recently installed by Hanlon-Buchanon throughout the field so that all contracted gasoline may be delivered to the Humble Pipe Line Company, at New London for shipment to Baytown, Texas.

Analysis of Raw Gas to Plant

COMPOUND	Mol. Percent	G. P. M.
Methane	39.10	.....
Ethane	13.60	.....
Propane	28.65	7.82
i-Butane	2.70	0.876
n-Butane	9.60	3.01
i-Pentane	2.10	0.76
n-Pentane	2.25	0.82
Hexane and heavier	2.00	0.86
	100.00	14.146

Analysis of Residue Gas from Plant

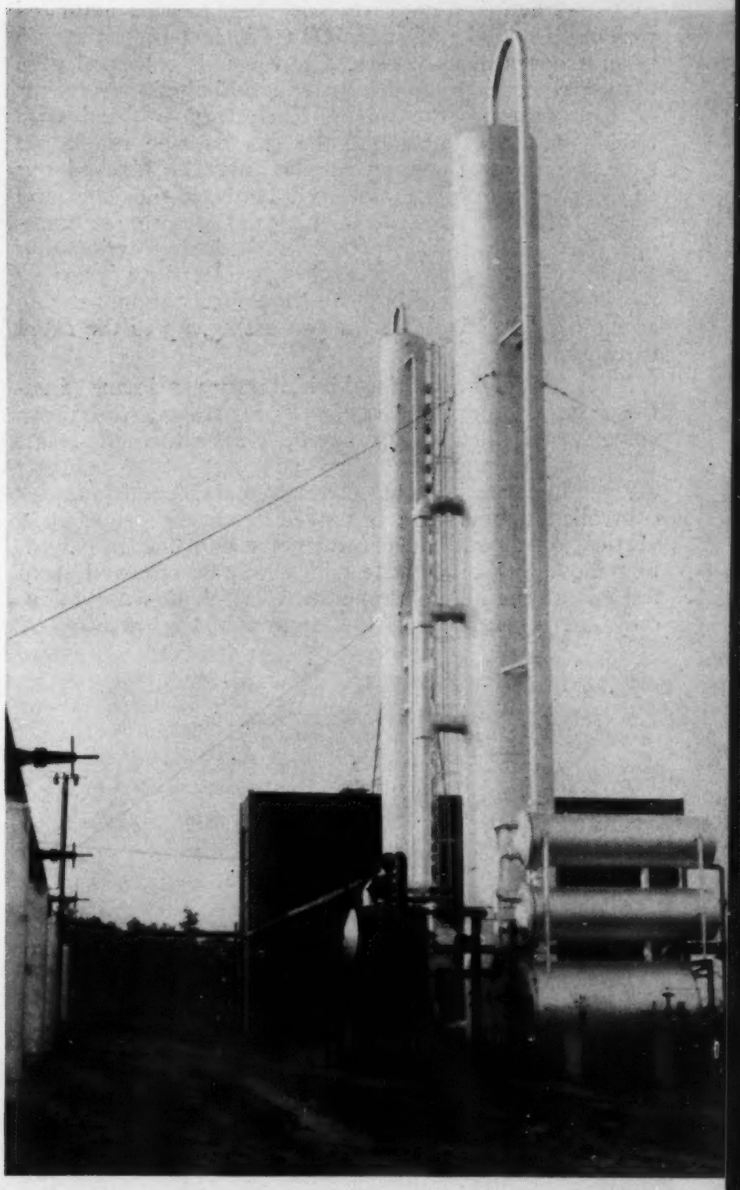
COMPOUND	Mol. Percent	G. P. M.
Methane	48.45	.....
Ethane	16.60	.....
Propane	27.60	7.541
i-Butane	2.08	0.676
n-Butane	5.27	1.650
	100.00	9.867

Operating Practice at Gilliland-General Plant

GILLILAND-GENERAL Gasoline Company recently completed a plant at Reed Switch, in Rusk County, East Texas field, which has some features not found in other plants of like character. Because of the low producing pressures which prevail in East Texas, coupled with the large amount of gathering lines, all plants in East Texas are equipped with compressors. This plant contains 9 twin engines, developing 230 horsepower each, having both low- and high-pressure gas cylinders. The gasoline recovery portion of the plant was designed to handle 15,000,000 cubic feet of gas, and sufficient space was provided to extend the compressor room to accommodate as many gas engine-driven compressors as will be necessary to take care of that amount of gas.

Only about 1000 wells have been connected to the gathering system, which provide approximately 6,000,000 cubic feet of gas daily, with an average plant production of about 3.7 gallons per thousand cubic feet of gas, stabilizing the liquefied product to a vapor pressure of 10 pounds, Reid. Gross production, or that produced by the recovery system before it is stabilized, is not measured but before it is pumped to the tower for the manufacture of the 10-pound product it has a vapor pressure of 40 pounds, Reid. East Texas gas is exceptionally richer in fractions of lower boiling range than desired in the manufacture of standard natural gasoline. The following analysis of the gas from wells surrounding Gilliland-General Gasoline Company's Reed Switch plant shows what might be obtained under ideal condensing conditions:

Compound	Mol. Percent	Gross Gallons Based Upon a 12,000,000 Cu. Ft. Throughput
Methane	44.13	66,200
Ethane	9.50	24,400
Propane	27.37	88,600
i-Butane	6.15	24,100
n-Butane	8.38	31,500
Pentane plus	4.47	44,400
Total	100.00	279,200



Columns in Gilliland-General Gasoline Company. Column in foreground is final gasoline stabilizer, with one in background as high pressure gas fractionator

However, under conditions imposed by market demands on this plant, the production is what is termed butane-free gasoline. As only about one half the available gas is being passed through the recovery units (6,000,000 cubic feet) the production is around 22,000 gallons, leaving approximately 72,100 gallons of the lower boiling fractions in the residue, which are revaporized and burned in a flare when vented from the reflux accumulators.

The gas is handled through this plant in much the same manner as practiced by other manufacturers of natural gasoline in East Texas, taking it from oil and gas separators in the field through gathering lines at a compressor-room suction of about 15 inches Hg. vacuum. The gas, upon being discharged from the low-compression cylinders at about 40 pounds is reduced in temperature through enclosed shell-and-tube condenser sections to 108°F. These condenser sections are placed upon steel supports near the side of the engine room, with the discharge from them connected to vertical

scrubbers to remove water and gasoline condensate. Each engine, being equipped with both high- and low-pressure cylinders, has its individual low-pressure cooler, separate from the general gas system.

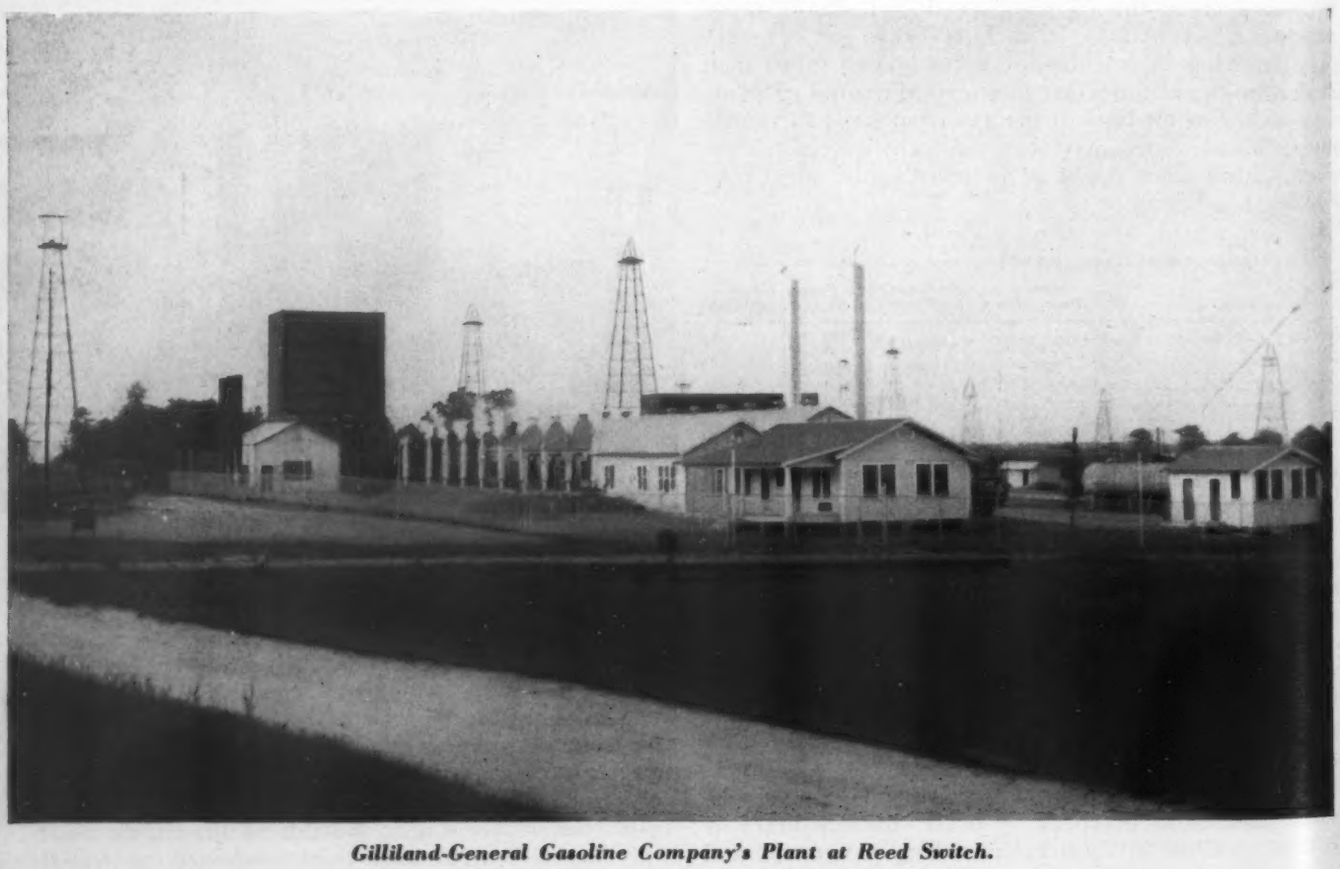
Suction to the high-pressure cylinders is obtained through short lines leading directly to the compressors individually, with this discharge entering a common header which serves to handle all of the high-pressure gas going to the recovery system. A single battery of high-pressure gas coolers is located near the high-pressure recovery column, which is operated at 270 pounds, gauge. This column, termed the primary fractionation tower, is 6 feet in diameter by 65 feet in height, containing fractionating plates with bubble caps arranged to handle a load of 15,000,000 cubic feet of gas at 275 pounds operating pressure. The tower is equipped with manholes at each bubble tray with bolted covers for ease in entering the tower. Each tray is fitted with bubble caps located above the gas passage nipples in such a manner that any number may be blocked out of service with plates inserted between the caps and the top of the nipples. By opening the column, any number of bubble caps on each individual fractionating tray may be opened for service, or closed by inserting the steel plates in order to adjust the column for any amount of gas available for processing, up to the rated capacity.

The gas entering the high-pressure primary fractionating column is cooled, passing through the gas cooler, controlled to an outlet temperature of about 170°F. with a temperature recorder-controller operating a valve in the water inlet-outlet by-pass. The gas under controlled temperature is passed from the cooler to a vertical scrubber, 4 feet in diameter by 8 feet in height, to remove any condensate which may be removed from the gas at the above temperature. With this operation, only gas is admitted to the column in the recovery of the gasoline fractions, liquids being disposed of through other equipment.

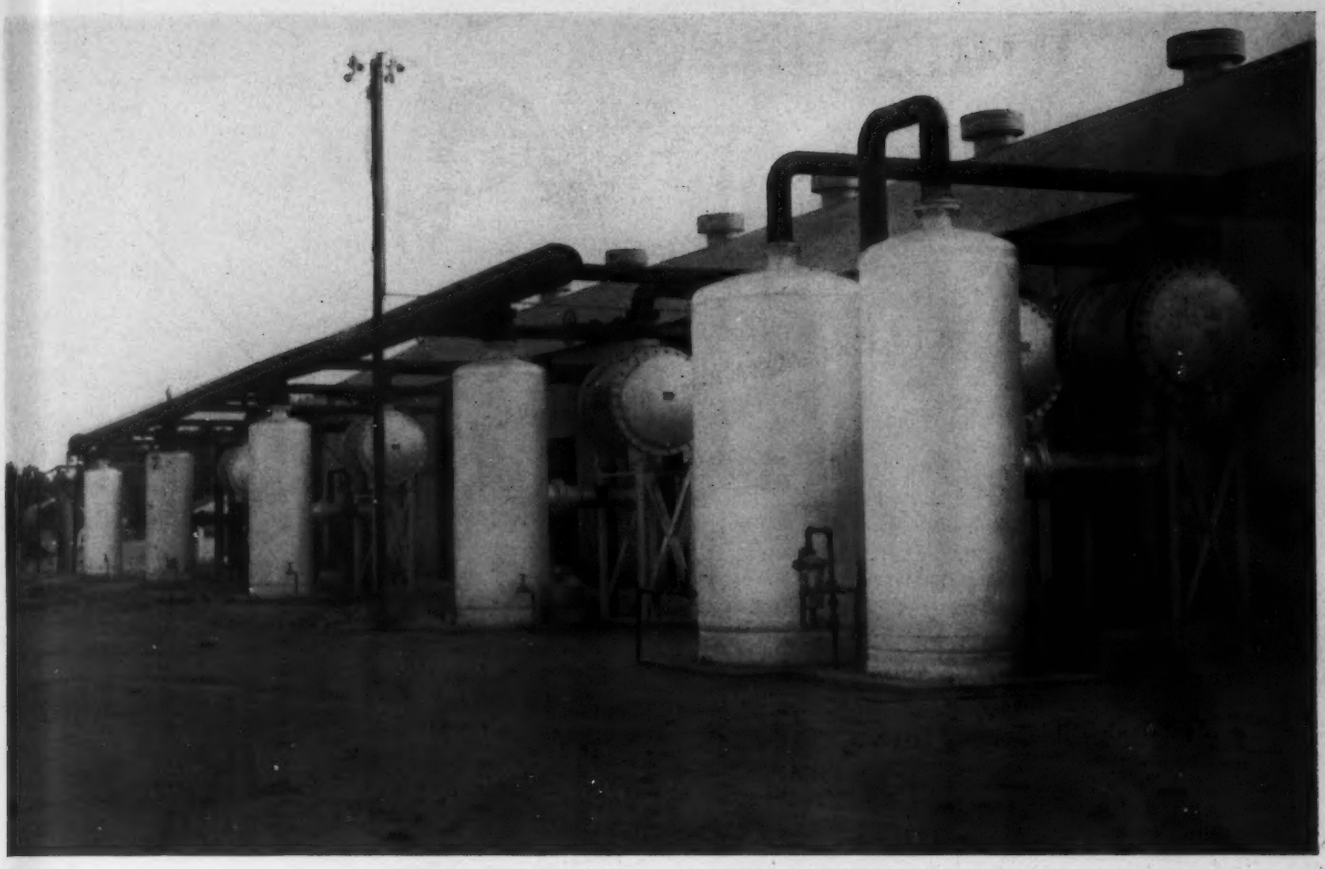
The gas is admitted to the side of the column at a point in balance between charged gas and column temperature, and passed upward through the tower in the conventional manner, with the exception that only a portion of the plates create the necessary contact between the ascending gas and the liquid upon the trays. The top of the column is maintained at approximately 120°F., which may be varied to suit operating conditions. The bottom of the tower is maintained at 222°F. with a steam-operated re-boiler placed beside the column which is operated at 250°F. Gas from the overhead line flows through two reflux condensers, tube-and-shell type with water control, with the gas and liquefied reflux material passing through an accumulator tank, 6 feet in diameter by 10 feet in length. Back pressure is maintained on the column and condensers in the line after the dry residue gas leaves the reflux accumulator, with a recording back-pressure regulation instrument.

Reflux is pumped from this accumulator with close-clearance pumps so that the desired column overhead temperature may be maintained. Water accumulating in the reflux receiver is automatically removed by a steam trap adjusted and equipped for water removal from low-boiling gasoline condensate. Excess reflux is disposed of in the conventional manner by permitting it to pass with the gas to the fuel lines and flares.

Gasoline with a vapor pressure of approximately 40 pounds, Reid, is passed under system pressure through shell-and-tube, gasoline-to-water coolers, to a surge tank, 50 by 30 feet in size, from which it is pumped to the secondary fractionator. A pump is used as a charge pump to remove the gasoline from the surge tank to the secondary column, operated at 175 pounds, gauge. The secondary column is 4 feet in diameter by 65 feet in



Gilliland-General Gasoline Company's Plant at Reed Switch.



Low-pressure gas coolers and liquid accumulators

height, equipped with plates and bubble caps, with a re-boiler and other accessories.

The charged gasoline passing to the secondary fractionating column passes through a shell-and-tube exchanger counter-current to the finished material from the re-boiler of the column, and enters at a selected point above one of three trays. Separation of the pentanes and heavier from the butanes and lighter is obtained by carrying a re-boiler temperature of 260°F., a column pressure of 175 pounds and a column top temperature of 160°F. Finished gasoline with a vapor pressure of 10 pounds, Reid, is withdrawn from the secondary fractionating column re-boiler and passed through the charge-to-bottoms exchanger with an after-cooler to obtain the desired temperature on the gasoline going to storage. The flow of the gasoline from the base of the column is controlled with a liquid-level float instrument, remotely controlling a valve on the line leading from the gasoline after-cooler.

Overhead vapors from the secondary fractionator are passed directly through a temperature-controlled condenser for the production of column-control reflux. This condenser is operated at a temperature of 142°F., but may be controlled to as low as 90°F., so that excess reflux will not be manufactured. As an extremely low vapor pressure natural gasoline is being manufactured, a large volume of lower-boiling fractions containing a major portion of the butanes are vented to a flare.

Water cooling in East Texas is more or less a problem for those who have been accustomed to conditions where wind velocities are higher and where a lower relative humidity prevails. The water in this plant is cooled in a 1200-gallon-per-minute tower, which contains 8 sections with a total length of 64 feet. Water entering the tower from the condensers and coolers has a normal summer temperature of about 98°F. and leaves the basin through the circulating pumps with a temperature of around 82°F. With this water temperature, processing may be carried out successfully, and gasoline enters the storage tanks from the final coolers at about 85°F.

While the wind velocity in East Texas is normally low, the soil conditions are such that finely divided sandy dust is occasionally picked up by the breeze, which if permitted to enter into the power cylinders of the engines would shortly cause abnormal wear. To prevent this occurring in the Reed Switch plant, Gilliland-General Gasoline Company installed a centrifugal type oil-washing air cleaner on each pair of cylinders.

COLUMNS

	Primary	Secondary
Top temperature	120° F.	160° F.
Base temperature	222° F.	242° F.
Kettle temperature	250° F.	260° F.
Column pressure	270 lb	175 lb
Condenser No. 1	110° F.	142° F. (controlled at will)
Reflux condenser	92° F.	138° F.
Gas pre-cooler	170° F.	.....
Condencer water out	93° F.	141° F.
Condenser water in	83° F.	83° F.

OTHER CONDITIONS

Stabil. gasoline exchanger	In 624° F.	Out 136° F.
Raw gasoline exchanger	In 101° F.	Out 206° F.
Gasoline cooler	In 132° F.	Out 85° F.
Water to tower	98° F.	.....
Water from tower	82° F.	.....
Production	30,000 gallons 40 pound, Reid, raw.	
Production	22,000 gallons 10 pound, Reid, finished	
Gas processed	6,000,000 cubic feet	
Gasoline content	3.7 G. P. M.	

Operations at Hercules Plant Described

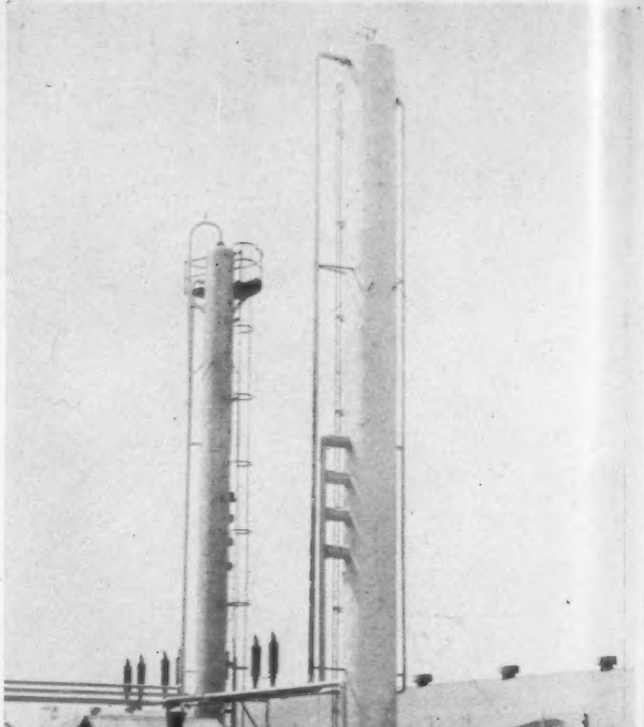
DUE to field conditions and favorable contracts made with producers by Hercules Gasoline Company, this company has found it necessary to enlarge its plant at Kilgore, Texas, by adding 4 250-horsepower gas engine-driven compressors. The company had 1400 wells tied into its gathering system prior to the enlargement program, but upon completion of the additions to the plant 1600 wells are producing gas for this plant. The enlargement program included the 4 new engines, the erection of a tail-gas absorber to recover residual pentanes and heavier and to process the raw gasoline manufactured to produce both propane and butane.

With the additions to the plant approximately 13,000,000 cubic feet of gas is processed daily. The volume from each lease depends upon the allowable individual well production. With an allowable per well of 20 barrels per day, each barrel of oil releases an average of 250 cubic feet of gas. This in turn depends largely upon trap and separator pressures, atmospheric conditions and the size of the gathering lines.

This company has laid in the field surrounding Kilgore, about 100 miles of gathering lines, the size calculated upon a basis of adequate lease service, intending to remove gas from the various traps with a minimum amount of back pressure. The principal vacuum mains were 20-inch pipe, with lateral sizes depending upon the number of wells. The field line layout, while not differing greatly from others in East Texas, was designed with the intention of holding a pressure of approximately one atmosphere on the traps when the wells are produced in an orderly manner.

Most of the producers of oil in East Texas arrange their flowing schedule so that an even distribution of gas may be spread out over the full 24 hours whenever it is physically and economically possible. Naturally, all of the leases cannot be included in the schedule so that the gas can be processed with the same continuous flow as if the wells were pumped continuously, but the schedule worked out by this company and the producers does eliminate overloading the compressors.

A header vacuum at the intake of the plant of approximately 15 inches, mercury, is necessary so that each individual lease be adequately served. Obviously the leases nearest the plant are subjected to the lowest absolute pressure and to prevent an excessive vacuum being pulled upon those traps, field regulators are provided at separators so that a predetermined absolute pressure can be maintained which will result in the greatest amount of gas and the highest gasoline content.



Hercules Gasoline Corporation, Kilgore, Texas, gas fractionator and final stabilizer

Two-stage compression is required in this plant to place sufficient pressure upon the recovery column and gas coolers to obtain the greatest efficiency. Intake headers for both the high- and low-compressor cylinders are placed directly above the intake ports, with the discharge headers buried outside the engine room. Control gates are placed at a convenient point where both the discharge and intake may be handled almost simultaneously. The power cylinders on the newer installation of engines are inverted with the exhaust pipes extended through the roof, each cylinder equipped with an individual muffler.

Water flowing over the cylinder jackets is cooled in an elevated louvre tower having 10 bays, while gas cooling and gasoline condensing water is conditioned in an 18-bay tower. Atmospheric cooling units are used in the cooling tower. The water is circulated by steam turbine-driven centrifugal pumps with a capacity of 7500 gallons per minute, while operating at a speed of 1800 revolutions per minute. The gallonage of natural gasoline manufactured depends upon the vapor pressure of the finished material, running about 40,000 gallons of 26/70 grade.

Humble Pipe Line Moves East Texas Gasoline to the Gulf Coast

DUE to the high propane-butane content of natural gasoline manufactured in East Texas, with the attendant desirability by refiners for these products as raw material for polymerization, Humble Oil & Refining Company and Hanlon Buchanan, Inc., have made the necessary arrangements for the bulk of East Texas output to be moved to the Gulf Coast. Hanlon Pipe Line Company, a subsidiary of Hanlon Buchanan, Inc., and Humble Pipe Line Company are the carriers for the products of natural gasoline plants.

Using an old eight-inch crude oil transportation system running from New London, in East Texas, to Baytown, on the Gulf Coast, Humble Pipe Line Company transports either the stabilized natural gasoline or the various fractions made at the plants. Hanlon Pipe Line Company acts as the gathering agent, delivering to the northern terminal of the Humble Pipe Line Company near the New London gasoline plant of the Humble Oil & Refining Company.

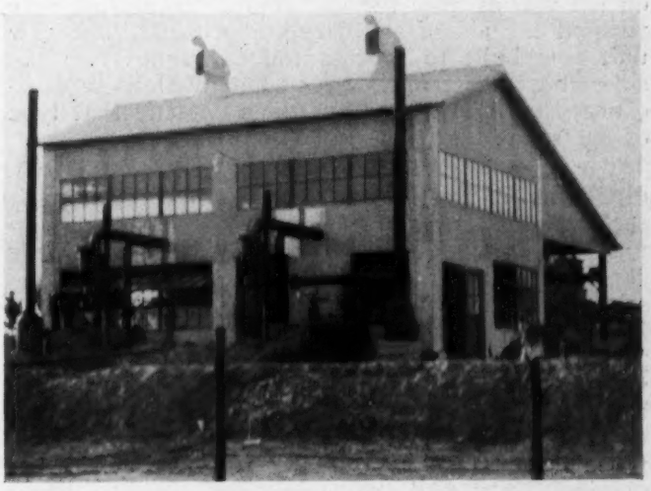
The eight-inch line was completely renovated, reconditioned and cleaned of all scale and other substances which might interfere with the movement of gasoline, or discolor the material in transit. The line, after being inspected, reconditioned and wrapped to prevent soil corrosion, was cleaned on the inside by washing with water, kerosene and caustic solution, each of which was pumped through the line at different times. While the line was out of the ditch, it was tested to determine what leaks might have developed while welding the collars so they could be mended before the line was lowered and covered.

Until the thermal polymerization plant which Humble Oil & Refining Company is building at Baytown is completed only stabilized natural gasoline is shipped through this line. After it is completed butane, propane, stabilized natural or the raw product direct from the accumulators will be shipped. Tentative plans indicate that the unstabilized gasoline will have a Reid vapor pressure of about 50 pounds, including some of the propane, all of the butanes and heavier. The gasoline received at Baytown will be refractionated for the removal of the lower boiling fractions desirable for thermal polymerization, and the higher boiling fractions used as blending material.

The station at the northern end of the line was located near the New London gasoline plant for ease of checking material by the company chemists. Two spherical pressure vessels were erected between the plant and the pipe line station to receive the gasoline before it is picked up by the pipe line pumps. Displacement meters measure the gasoline from the various plants at the station tanks. A complete testing laboratory was built for analyzing the various products to determine the value of the material.

The station consists of two units, the motive power being gas/Diesel vertical, six-cylinder, four-cycle engines. These are in a steel building, with a brick firewall between the engines and pumps.

The pumps, one connected to each engine, are of the multi-stage centrifugal type with a capacity of about 9000 barrels per day without an intermediate booster station between New London and Baytown. The difference in speed between the relatively slow gas engines and the high speeds necessary for centrifugal pump operation is obtained by geared speed increasers on the pump side of the station. The cover for the pumps, instead of being the usual type of building construction, consists of an extension of the engine room roof, with the sides open.



Humble Pipe Line Company's New London station, built to transport natural gasoline from East Texas to Baytown

Suction and discharge controls are outside the covered space where the pumps are located and are worm and sector operated lubricated plug valves. The essential equipment for the insertion of pipe line scraping devices was also installed in the manifold so that the line may be maintained free from interior obstructions.

The amount of natural gasoline available for transportation through this line will vary widely, depending upon the propane-butane content. Gas produced in East Texas averages roughly 340 cubic feet per barrel per well per day, with an everage content of 15 gallons per million cubic feet, including propane, the butanes, pentanes and heavier.

Compound	Volume Percent	Gallons per M cu. ft.
Methane	44.13	5.50
Ethane	9.50	2.02
Propane	27.37	7.45
i-Butane	6.15	2.00
n-Butane	8.38	3.00
Pentane Plus	4.47	3.70
	100.00	23.77

SOLVEX

Operating Cracking System of *Novel Design*

TO ROUND out a complete refining operation in East Texas, Solvex Refineries, Incorporated, recently completed a new type cracking unit which operates in conjunction with the original skimming plant. The new proceses include the Dubbs cracking facilities with a vapor-recovery unit operating on the vapors from the unit under process pressure without the aid of auxiliary compressors. The new unit was built to process topped crude from the skimming plant, but may be operated as a dual-charged furnace when conditions demand that type of operation.

The steps in the refining operation include simple distillation of East Texas crude oil by processing it through the skimming plant, with residuum removed from this unit at about 26.5° A. P. I. which is charged to the cracking plant. A small amount of salt is present in some of the crude, and provision is made to remove it before it enters the skimming plant pipe still. All possible provisions have been made for conservation of heat by installing various heat exchangers so that the fresh crude may be partially distilled before it is subjected to the heat in the pipe still. Temperatures as high as 315° F. are obtained by use of the preheaters, vapor-to-charge exchangers and skimming plant bottoms-to-charge units.

The crude at this temperature is passed through the long horizontal salt-removal equipment at about 180 pounds, gauge, where it is washed with water. Leaving the salt settler, the crude flows to the primary flash tower where the lighter vapors are removed, to flow to the debutanizing column. The vapors from this unit are piped to the cracking plant recovery system where those fractions that go to make a desirable component of motor fuel are saved. The "debutanized" crude then is pumped to the skimming plant pipe still where it is heated in a conventional bank of tubes to 585° F., and transferred immediately to the main flash column.

Topped crude removed from the base of this column makes up the principal stock for cracking. Vapors from the flash column enter the bubble tower for complete fractionation, with straight-run gasoline composing the stream from the top of the column, and gas oil from the base. Naphtha, kerosene and distillate are all removed from points on the side of the column, entering strippers beside the tower for qualitative control. Two cuts are mixed which are removed from the main flash column and the fractionating column. These are topped crude from the base of the first column and gas oil from the stripper through which this cut travels upon being drawn from the base of the bubble column. The blended mixture is what is normally charged to the cracking column in the manufacture of high-octane motor fuel and low-gravity fuel oil.

Approximately 1600 barrels of raw oil is charged daily to the cracking plant by a 7½x5x6-inch duplex pump, operated at about 26½ strokes per minute. This pump directs the oil through a 2-inch line to the bubble tower, entering above the eighteenth tray, numbering them from the top downward. The column is 5 feet 6 inches in diameter by 59 feet 3 inches in height, containing 27 bubble trays. The walls of the column are of two thicknesses of steel; the lower section having 11/16-inch walls while the upper section was made from 9/16-inch material.

Base material from the lower section of the bubble column is removed through a 10-inch line to the gas-engine-driven hot-oil pump, which has a bore of 5½ inches and a stroke of 18 inches. This pump operates at a normal speed of about 43½ revolutions per minute and at about 615 pounds, gauge. The suction to the pump is made up of two separate lines connected to a manifold so that either the material from the base of the bubble tower may be handled as the charge to both sides, or it may be handled by one side of the pump while the other is pumping a different material, for example, naphtha, to be reformed. The discharge is likewise made up of two separate lines leading to the furnace, where the material handled by both sides may be passed through both banks of tubes, or the charge kept apart while passing through the banks of cracking and/or reforming tubes.

The furnace is an up-flow doubletype fired from both sides. It is of the suspended tvpe of construction, having a steel structure upon which all of the essential features are hung; walls, tubes, breeching (to the stack) and combustion chamber. A fire wall extends the full length of the furnace, dividing the interior into two compartments. Twenty burners are set in the floor of the furnace close to the center wall, firing upward and at such an angle that the flames impinge against the wall on both sides, with the gases of combustion owing upwards through the breeching to the stack at one end of the unit.

When the hot-oil pump is handling the same material on both cylinders, the charge enters the fur-

nace at both sides near the top, flowing through two sets of radiant tubes from top to bottom. The tubes are 2⅛ inches inside diameter and 2⅝ inches outside diameter, 30 feet in length. The tubes on both sides of the furnace converge into a common 5-inch transfer line which leads to the reaction chamber. Furnace temperatures are as follows:

N-E Section	1385° F.
N-W Section	1425° F.
S-E Section	1400° F.
S-W Section	1410° F.
Stack	940° F.
West Transfer	950° F.
East Transfer	950° F.

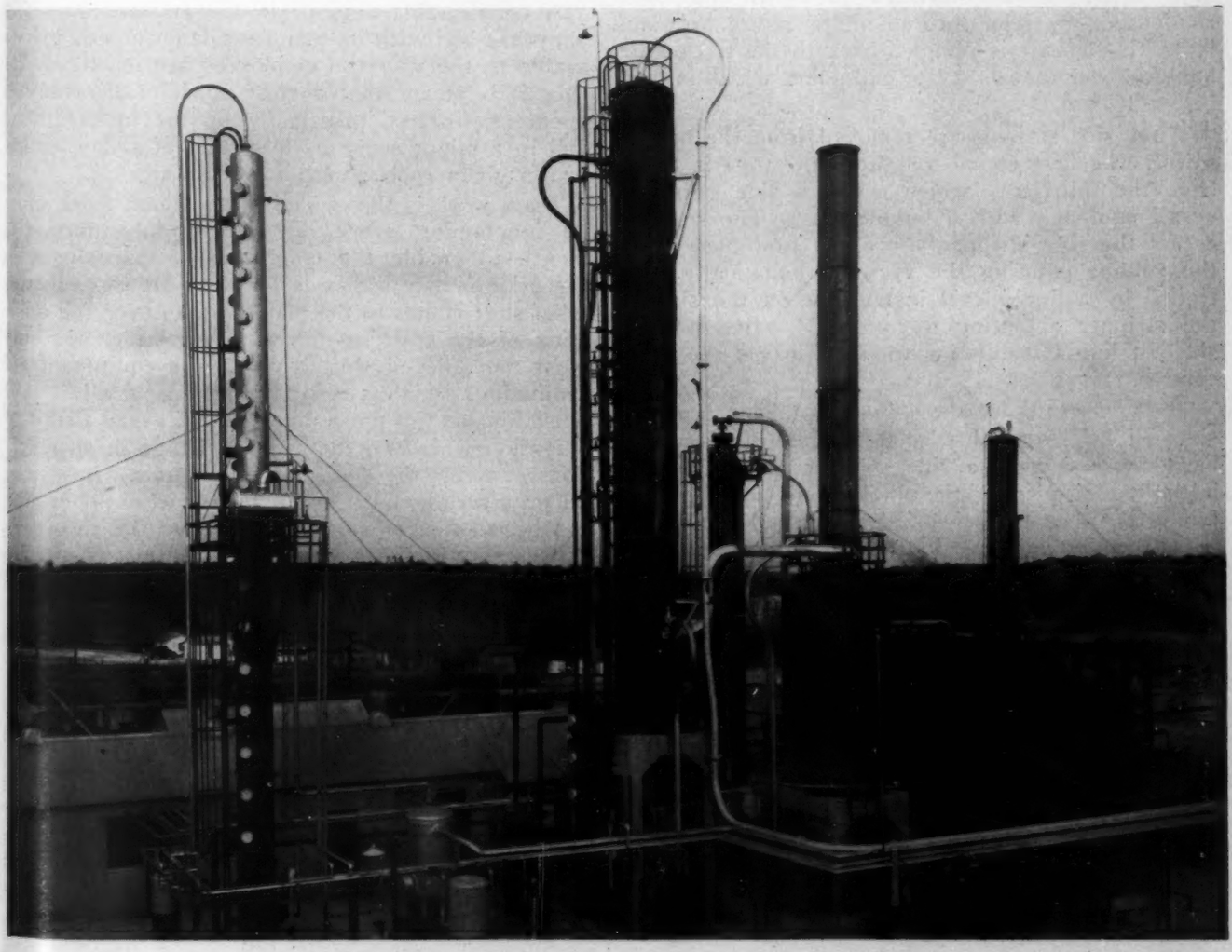
The transfer lines at the point of joining with the common line to the reaction chamber have an operating pressure of 610 to 620 pounds. The flow through the reaction chamber is from top to bottom, with a chamber pressure of 275 pounds, gauge. The chamber is 4 feet in diameter, outside measurements and 40 feet in height. The walls of the chamber are 4 inches thick with an application of 5 inches of insulation. To prevent undue accumulation of coke, the reaction chamber is equipped with a wall-washing lime through which liquids are pumped to the top of the chamber.

The cracked material, both vapor and liquid, leave the reaction chamber at the base through a 3-inch slide valve in a 6-inch line leading to the flash chamber. This vessel is 10 feet in diameter by 18 feet in height, having 2½-inch walls which are covered with 4 inches of insulation. Vapors from the top of the flash chamber are led through an 8-inch line to the bubble tower for complete fractionation.

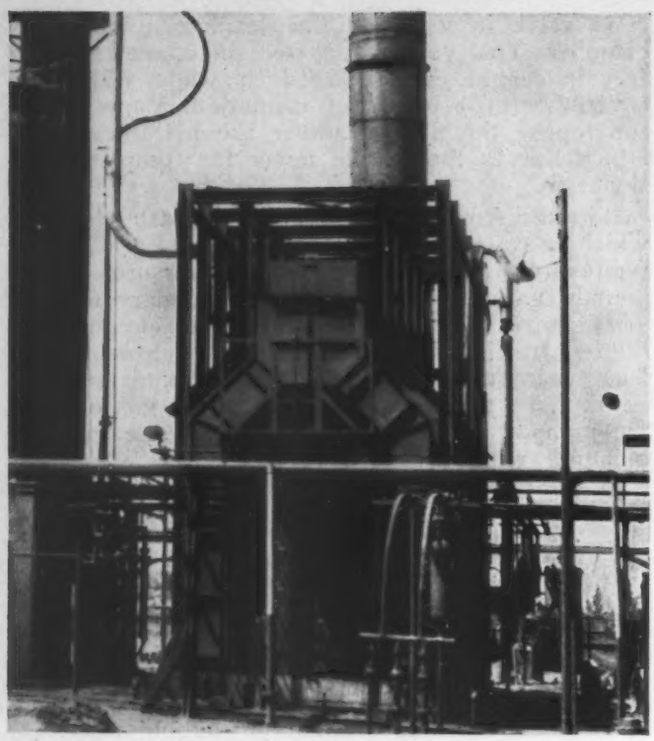
Bottoms from the high pressure flash chamber, which has a top temperature of 800° F., a bottom temperature of 740° F., and a pressure of 103 pounds, gauge, are vented to a secondary flashing vessel in order to further strip the residuum of its lighter fractions. Bottoms from the low-pressure flash chamber are reduced to approximately 1.3° A. P. I. by the removal of the heavy gas oil, and are pumped by automatic control to storage after blending with a stream of gas oil to 8° to 80° A. P. I. The material so blended has the following characteristics:

Gravity	8-10° A.P.I.
Flash, open cup	260° F.
B. S. & W.	.3%
Viscosity	240

Vapors from the high-pressure flash chamber enter the fractionating column, or bubble tower, at about 735° F., flowing from the base upward through the 27 bubble plates. Top material is gas-



Solvex Refineries plant at Gladewater, Texas



Side-fired heaters

oline vapors leaving through an 8-inch line to 2 condensers, in series, to distillate reflux accumulator. Condensate is pumped back to the top of the bubble tower for control of end-point, which is held below 400° F.

Three side streams are removed from the bubble tower. The first (numbered from the top) is taken from the third tray which enters a side stripping vessel equipped with 6 bubble trays. The fraction enters the side stripper above the first plate with the volume entering the vessel automatically controlled by a liquid-level instrument on the side of the stripper actuating a controlled valve on the side-cut line at the point where it leaves the main column.

The next cut down the column is taken off at the sixth, eighth, or tenth tray at the rate of about 150 barrels per day, to a side stripper to control the initial boiling point of the oil. This cut has a gravity falling between 30 and 40° A. P. I. and is used as an absorption medium in the vapor-recovery unit. The vapors from the side stripper, removed with process steam, are vented back to the seventh tray in the bubble tower for further fractionation.

The third cut taken from the column comes off at either the thirteenth or seventeenth tray to a side stripper to remove lighter fractions withdrawn with it, and is pumped to the recovery unit as reboiler oil. The side-stripping vessel set for this cut is 2 feet in diameter and 16 feet 8 inches high, with 5/16-inch walls, insulated with 2 inches of material.

Sufficient pressure is held on the pressure distillate, or cracked gasoline receiving drum, and parts of the initial stages of the crude skimming plant, so that vapors not condensed at the temperatures and pressures maintained may be transferred to the recovery unit where they are absorbed and fractionated with the other material. The recovery unit consists principally of a dual column, or one superimposed upon the other, the lower section being the stabilizer while the upper section recovers the lighter fractions from the various parts of the plant. Heating of the reboiler is accomplished with the side cut removed from the bubble tower with the base maintained at 290° F.

Following are some of the products manufactured:

	Straight Run Gasoline		Cracked Gasoline Two Grades		Debutanized Recovered Gasoline
	Summer	Winter	No. 2	No. 1	
Gravity..	60/62° A.P.I.	62/64° A.P.I.	60/62°	64/66° A.P.I.	78/80° A.P.I.
I. B. P...	90°F.	84°F.	88°F.	80°F.	68°F.
10%....	150°	145°	126°	120°	104°
50%....	250°	240°	251°	245°	250°
90%....	360°	352°	356°	348°	298°
E. P....	400°	395°	396°	392°	300°
Doctor..	Sweet	Sweet	Sweet	Sweet	Sweet
Corrosion	Neg.	Neg.	Neg.	Neg.	Neg.
Gum....	.....	.....	15 mg.	15 mg.	.....
Color....	30	30	Natural	Bronze	30
Octane..	58	60	65	68	.....
V. T.....	8 lbs.	11 lbs.	9 lbs.	9 lbs.	20 lbs.

In addition to the above products, several grades of solvents are manufactured, as well as blending naphthas, tractor distillates, and gas oils, with residuum from the cracking plant disposed of as fuel.

A considerable amount of the success the company has had with its plant at Gladewater is attributable to the way the employees are managed. By this, it is meant that a close spirit of harmony is apparent, fostered principally by the management, and in a minor sense by a system of prizes, or rewards given each month for team work.

Team work is the objective, and team work must be functioning every day during any particular month to enable the employees to participate in the prize money set aside for the purpose. When a relief shift comes to the plant to take over the operation of the cracking plant, for example, not only must the relieved shift have all the equipment coordinating and the streams to specification, but must inform the oncoming shift of every detail of operation which might effect a change in specifications or affect the operation of the unit. Those who are on a certain shift for the month whose operation has been satisfactory, determined by the recording instruments in the control room and elsewhere, are given prizes, if they have been operating the particular unit better than the other shifts.

The test finally comes from plant yields, quality of products, and acceptance by the ultimate bulk purchaser. Tank car loads of products leaving the rack must meet the specifications of the order, and arrive without outlet cap or dome cover leaks. Therefore, if any of the employees fail in conducting his part of the operation of the plant, with the product off specification, tank cars in bad condition, the entire personnel fails. On the other hand, if each employee co-operates fully with all others, catching difficulties in time to prevent products from going off specification, prizes are awarded according to grades of operation.

Premier Generates Electrictiy *for* Operations

WHEN Premier Oil Refining Company built its plant at Longview, in East Texas, steam was thought of principally as a processing medium to assist in refining the crude by admitting it to the columns and other points where necessary. All pumps, with the exception of three, are driven by electricity generated in the plant. The generating station is located at a safe distance from the distillation equipment and contains three units, each capable of generating 100 KW.

The power units are 4-cylinder, 4-cycle gas engines directly connected to the generators. The generators are 125 KVA units with individual exciters driven by belts from grooved pulleys, each excited 125 volt, 26 ampere generators. The generators have a rating or power factor of 80, when running at 514 revolutions per minute. A complete control board controls the current with switches for distribution throughout the refinery. Only to of these units are required during normal operation, one being held in reserve, so that any of the units may be serviced without interrupting operation.

Current in the generating room is carried through underground conduit, as is that going from the switchboard to the various motor-driven units in the plant. Hazards are thereby eliminated due to interference with wiring by trucks moving through the yard. Maintenance of cables is reduced to a minimum, the conduit being buried in such a manner that piping may be removed without disturbing the electrical transmission equipment.

Outlet boxes and other fixtures where additions to the power or lighting circuits may be connected are located at various points over the plant so that new conduit need not be laid when changes in operation are made. Lights for offices, employees' residences and for yard illumination are furnished by the generating room.

The refinery is a complete unit manufacturing various types of petroleum products. Maintenance of equipment is stressed and is on a par with operation. Appearance of the plant as a whole is maintained to a degree that would be a credit to plants of much larger size, with a fresh coat of paint applied at intervals.

Interior of electrical generation building, Premier Oil Refining Company, Longview, Texas

Gasoline Plant *Operation in the* Rodessa Field

J. C. ALBRIGHT

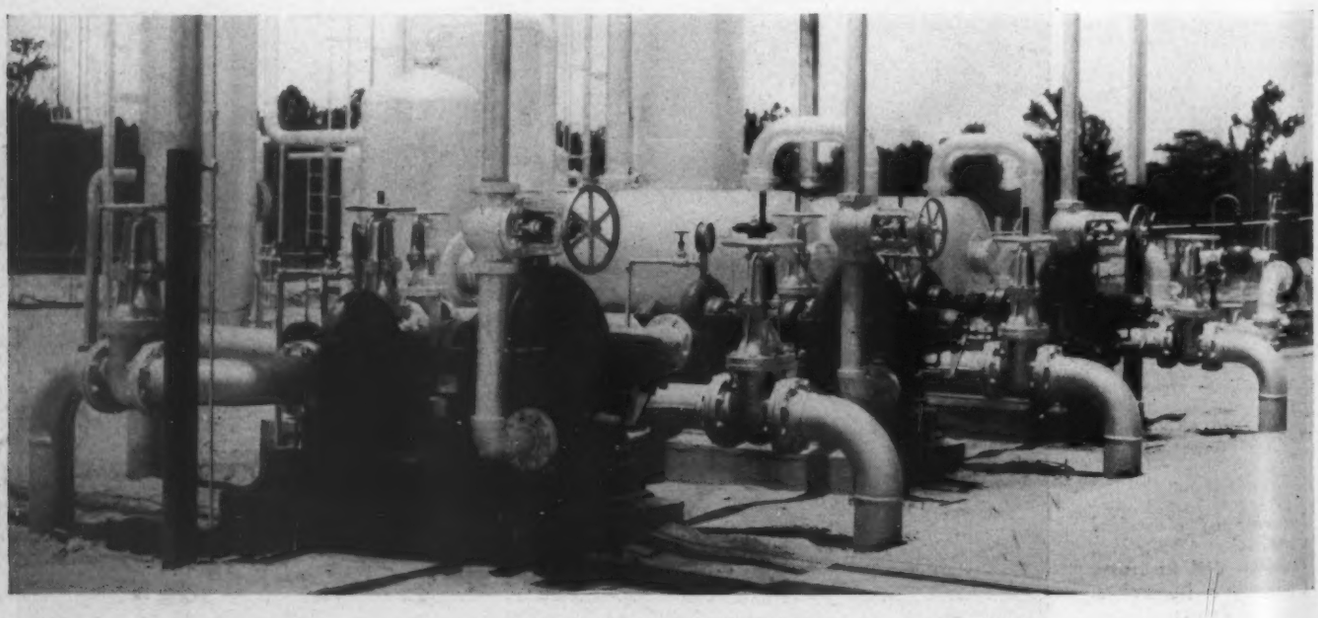
OPERATING upon gas produced from 13 wells on a 120-acre lease, Pelican Oil & Gasoline Company's* absorption gasoline plant averages around 40,000 gallons of gasoline daily. Gas produced with the oil in the Rodessa field is not so rich in gasoline fractions, neither has it a large volume of propane and butane, but the pentanes and heavier will permit production of about one gallon per thousand cubic feet through a well operated plant.

The plant is a combination high- and low-pressure absorption unit, taking gas from two-stage separation in the field immediately surrounding it. The high-pressure gas is released from the first stage separation and delivered to the plant through a separate gathering system. The low-pressure gas, coming from the second stage separation, is delivered to the plant through other lines. Large volumes of gas from a small area makes it possible to operate the plant with a small amount of gathering lines, and the dual system is not extensive. Under certain conditions, as much as 50,000,000 cubic feet of gas has been produced from the 13 wells, coming into the plant under sufficient pressure that no compressors are needed.

*Since acquired by Tide Water Oil Company.

The absorption equipment consists of three columns, one used in processing the high-pressure gas, 4½ feet in diameter by 50 feet in height. The other two are the low-pressure vessels, 7½ feet in diameter by 40 feet in height. The high-pressure absorber receives the gas from the first separation in the field, which is naturally much leaner than the low-pressure gas, through a separate system as stated above, which enters the plant through a line attached to a vertical scrubber to remove all condensate and oil before it is introduced to the absorber. The line leaving the top of the scrubber is placed in a horizontal position with sufficient length that the gas may be measured by an orifice meter. The scrubber is equipped with liquid-level control instruments and automatically dumps what fluid may be separated from the gas in the scrubber, from the base into lines leading to tankage where it is again picked up and pumped back to field tanks to mix with the regular production from the lease.

The low-pressure line enters the plant at the same point, and is connected to a horizontal scrubber, which is used for the same purpose as the high-pressure vessel. It also has a line leading from the upper portion with the horizontal section running standard distance for a meter flange so the gas may be measured separately by the use of an orifice meter. Both the high- and low-pressure lines leading from these scrubbers drop downward through risers to headers under the surface of the sandy soil. Weld-



Pump battery and connections

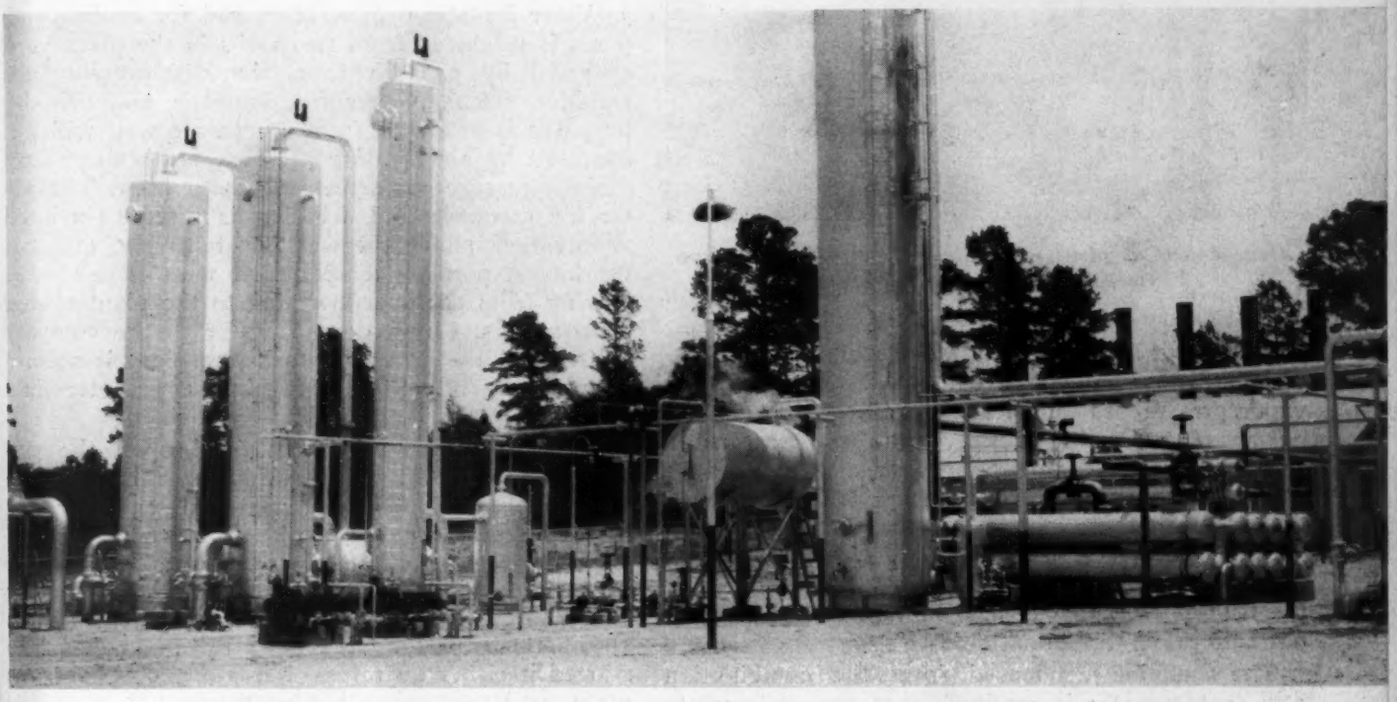
ing ells were used to make the 90° turns in the piping instead of flanged fittings.

The absorbers follow closely to general engineering practice, with bubble trays and counter-current flow of oil and gas. Taking the low-pressure gas first, it enters the two low-pressure vessels in parallel, with lean oil pumped to the top section of each column falling from one tray to the next below until it accumulates in the base, where it is removed by an automatic liquid-level controller. The high-pressure vessel is of conventional design, with the gas and oil flowing in the same manner as the low-pressure absorbers. However, the rich oil from the liquid section in the base of the high-pressure absorber is automatically led to the base of the low-pressure absorbers instead of to a regulation vent tank.

The rich oil removed in this manner is given an opportunity to release the lower-boiling fractions in solution with the absorption oil to the oil in the low-pressure absorbers. The desirable fractions that may be released with the propanes and iso-butane are thereby reabsorbed in the oil flowing downward through the low-pressure unit, instead of being picked up by a tail absorber for recollection. Liquid-level controllers are used on the base of all three towers to remove the oil, and the high-pressure oil enters the low-pressure absorbers at the base under such pressure that will continue the flow in the proper direction.

Gas from the top of the two low-pressure absorbers, not being under high pressure, is passed through scrubbers to remove what oil might be entrained with the gas and thence to an open space some distance from the plant and burned. The high-pressure gas, being under approximately 325 pounds, is directed through pipe lines to the surrounding field for lease fuel, after passing through a scrubber to dry it of entrained oil. To protect the vessels and accessories at the absorbers, twin safety valves were installed on the stripped gas lines as they leave the top of the columns.

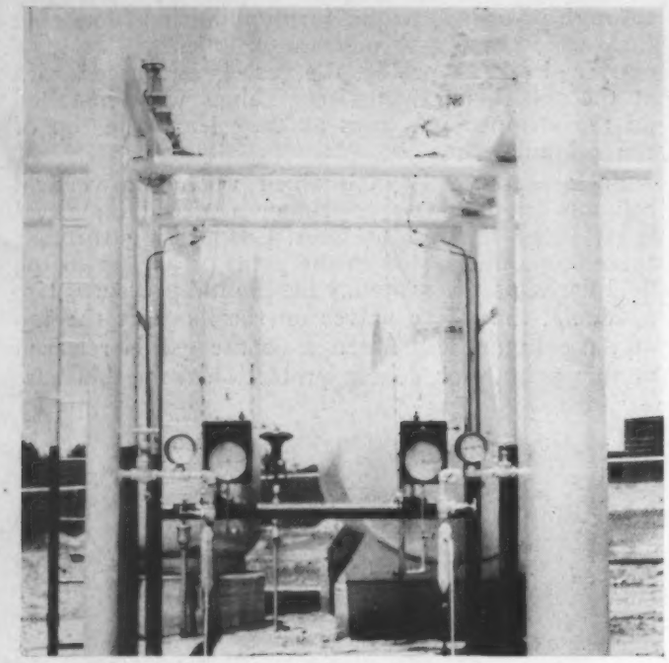
Back pressure is maintained upon the vertical columns by adequate instruments placed on aerial loops above the residue lines. Gas passing through these loops is directed to the point of use, or to the field flares, as the case may be. Should pressures rise suddenly, the safety valves on the loops at the top of the columns will function as the gas is released at this point. For double protection from this hazard, a second pressure-controlling instrument is installed on the header where the gas from the top of the absorbers enters the distributing system. This instrument is set at a pressure slightly above the working pressure of the columns so that gas may be released quickly without danger to men or equipment.



Absorption and distillation equipment of Pelican Oil & Refining Company at Rodessa, Louisiana

Fuel for the five oil-country-type boilers is removed from the residue system between the back pressure release valve and the residue safety valve on the vent line. These boilers provide steam for processing, for preheating the rich absorption oil and for heating high-pressure gas used in oil and water circulating turbine-driven centrifugal pumps. They are located in a steel building and are equipped with automatic water-feed controls.

The rich oil from the base of the low-pressure absorbers is handled by high-pressure gas-driven turbine centrifugal pumps which directs it to the distillation system exchangers, preheaters and to the combination still. This unit has a capacity of 50,000 gallons of finished gasoline daily, and is 7 feet in



Arrangement of plant scrubbers, Pelican Oil & Gasoline Company at Rodessa, Louisiana

diameter by 56 feet in height. Gasoline vapors removed from the oil are controlled to the desired vapor pressure as they leave the top of the column by pumping gasoline back over the tower as reflux. Condensation is obtained in conventional sections placed in a cooling tower at the side of the plant. Very little difficulty is encountered in this plant in manufacturing standard grades of natural gasoline, due to the very low propane content of the gas from the field. 26/70 gasoline may be manufactured without additional fractionation.

The gasoline condensed from the combination still-dephlegmator is received from the coolers into a horizontal receiving vessel set beside the column from which the required amount of reflux is pumped to control the end point of the finished product. That not needed for reflux, constituting only a small fraction of the finished product, is released from the accumulating vessel through an automatic liquid-level control instrument and travels directly to the 14-unit storage battery.

All pressures maintained upon the system, absorption and distillation, are controlled by automatic instruments. Those points where it is necessary to maintain a record of operation are equipped with recording instruments as well as controlling. The control room is located between the boiler room and the distillation equipment to make it convenient for the operator to watch the operation of the plant with a minimum amount of moving about, and also to place him in the approximate center of activity. All recording-controlling instruments were placed on a common control panel in this building, and after becoming familiar with the pressures and temperatures required, a glance at the group of instruments will give the operator a complete picture of conditions at that time, as well as what may have happened since the fresh chart was placed under the pens.

Exhaust steam from the rich oil preheaters is used to raise the temperature of the gas in the turbine drive system so that it will be most effective and to prevent frosting of the impellers. Sufficient pressure is available due to the high operating pressure of the gas coming from the first stage separators in the field. Pressures upon the high-pressure absorber are usually held at about 325 pounds. Three centrifugal pumps are in use in the absorption-oil circuit, one which handles the lean oil to the high-pressure absorber, one to the low-pressure units and one removing the oil from the base of the low-pressure absorbers to the distillation apparatus. Centrifugal pumps of like construction also are used to pump water over the cooling tower.

Water for steam generation and for cooling purposes is produced from two wells in the plant yard, operated by gas lift from the high-pressure gas residue system. Water for domestic and drinking purposes is produced from a separate well which is operated by air lift. Air pressure is obtained from a high-pressure gas-driven air compressor. The water for domestic and drinking is lifted to a small supply tank above the well constantly, to maintain the lowest possible temperature, with excess water flowing from the overflow pipe to the plant system makeup pits. Circulation of water to the company houses and the other points in the plant is secured by pumping it constantly against a predetermined pressure.

Constant pressure is maintained upon the gasoline in storage by using residue gas. Each of the 14 tanks is equipped with safety valves to prevent excessive pressure being placed in them, as well as a pressure controller connected to a common line attached to the upper side of the vessels. Pumping out from the storage tanks for shipment also is automatic in part in that after the pump has been started it either operates, or is stopped by pressure upon the loading line. High-pressure gas is used as the prime mover for this pump, taken from the same point in the residue system as that used for circulating and reflux pumps in the plant.

Gas in Rodessa is deficient in propane and the butanes, compared to East Texas gas for example. An analysis of a typical East Texas gas shows that it contains approximately 10.66 gallons per million cubic feet, or a volume percent of 37.26, while Rodessa gas contains only .949 gallons per million cubic feet, or a volume percent of 3.22. With this deficiency, large volume production of desirable polymerization material will not be produced in Rodessa, unless a radical change in gas characteristics occurs as the pressures decline.

Gas Analysis Pelican Oil & Gasoline Company, Rodessa, La.

COMPOUND	Volume Percent	Gallons per Million Cubic Feet
Methane	93.62	.....
Ethane	1.13	.....
Propane	1.70	0.464
i-Butane	.57	0.185
n-Butane	.95	0.300
I-Pentane	.42	0.150
n-Pentane	.45	0.160
Hexanes and Heavier	1.16	0.500
	100.00	1.759